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# The association of premorbid chronic pain and postconcussive syndrome following mild traumatic brain injury

## **Abstract**

This archival study explored differences in adaptability after concussion between those with and without premorbid chronic pain, in an effort to enhance our understanding of factors that are associated with the functional expression of impairment, disability, and variability in functional outcome following mTBI. Participants for this study included postconcussive patients presenting for treatment at a brain injury rehabilitation center in Portland, Oregon. Patient information and scores obtained on the Mayo-Portland Adaptability Inventory-4 (MPAI-4), a measure designed to evaluate functional outcome following brain injury during the post-acute period, was collected and analyzed to determine differences between groups. Separate independent samples *t*-tests revealed that premorbid chronic pain was associated with greater subjective impairment and lower levels of adaptability following mTBI. This finding suggests that premorbid coping vulnerabilities associated with chronic pain symptomology may play a predominant role in mediating the impact of functional impairments associated with PCS.

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THE ASSOCIATION OF PREMORBID CHRONIC PAIN AND POSTCONCUSSIVE  
SYNDROME FOLLOWING MILD TRAUMATIC BRAIN INJURY

A DISSERTATION  
SUBMITTED TO THE FACULTY

OF  
SCHOOL OF PROFESSIONAL PSYCHOLOGY

PACIFIC UNIVERSITY  
HILLSBORO, OREGON

BY  
SARAH ELIZABETH COLLINS  
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REQUIREMENTS FOR THE DEGREE  
OF  
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## ABSTRACT

This archival study explored differences in adaptability after concussion between those with and without premorbid chronic pain, in an effort to enhance our understanding of factors that are associated with the functional expression of impairment, disability, and variability in functional outcome following mTBI. Participants for this study included postconcussive patients presenting for treatment at a brain injury rehabilitation center in Portland, Oregon. Patient information and scores obtained on the Mayo-Portland Adaptability Inventory-4 (MPAI-4), a measure designed to evaluate functional outcome following brain injury during the post-acute period, was collected and analyzed to determine differences between groups. Separate independent samples *t*-tests revealed that premorbid chronic pain was associated with greater subjective impairment and lower levels of adaptability following mTBI. This finding suggests that premorbid coping vulnerabilities associated with chronic pain symptomology may play a predominant role in mediating the impact of functional impairments associated with PCS.

*Keywords:* mild traumatic brain injury, postconcussive syndrome, chronic pain

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*To my parents, whose love and support have always made the realization of my dreams seem possible, and to Jeff, who gave me the strength to follow through with this one.*



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## INTRODUCTION

The prevalence of chronic stress-related disorders is rising around the world and has been a major focus of research in recent years. Mirroring the rise of stress-related disorders is the increasing incidence of traumatic brain injury (Schneiderman, Braver, & Kany, 2008). Traumatic brain injury has emerged as one of the most significant health problems facing North America and the world at large. It is currently the number one cause of death and disability among younger generations, with an estimated 1.5 to 3 million individuals in the United States being affected each year (Centers for Disease Control and Prevention; Langois, Rutland-Brown, & Thomas, 2004). Despite these numbers, the true incidence of brain injury is likely to be grossly underestimated, with as many as 25% of brain injuries receiving no medical treatment of any kind (McCrea, 2008). The vast majority of unreported and untreated cases are believed to involve mild traumatic brain injuries, or concussions, which most frequently result from falls and motor vehicle collisions (Centers for Disease Control and Prevention, 2007).

Mild traumatic brain injury (mTBI) has become the most common neurological condition in North America, with 70-90% of all treated brain injuries falling into this category (Bazarian et al., 2005). Mild traumatic brain injury has been defined as a traumatically induced physiological disruption of cerebral function, as manifested by at least one of the following: loss of consciousness; the presence of retrograde or anterograde memory loss; alteration in mental status at the time of the trauma; the presence of physical symptoms potentially related to brain dysfunction such as nausea, headache, dizziness, or visual aberrations; and/or development of post-injury cognitive deficits that are not better explained by emotional factors (Mild Brain Injury Committee, 1993). To qualify as a “mild” traumatic brain injury, Glasgow Coma Scale scores must fall within the range of 13-15 without worsening, post-traumatic amnesia must be

limited to a 24-hour period, and loss of consciousness should not exceed 30 minutes (Williams, Levin, & Eisenberg, 1990).

The majority of individuals who incur an mTBI experience acute cognitive and behavioral effects, symptoms that will fully resolve within a 12-week period for the majority of people (Meares et al., 2007). However, approximately 10-15% of individuals who seek medical treatment for mTBI go on to report persistent cognitive and behavioral complaints (Stein & McAllister, 2009). When chronic difficulties related to mTBI persist after a 12-week period, postconcussive syndrome (PCS) may be diagnosed (American Psychological Association, 2000). PCS refers to a constellation of cognitive, emotional, behavioral, and physical symptoms that persist and are disabling for a duration of time that long exceeds expected recovery times following a concussion (Greiffenstein & Baker, 2001).

The incidence of postconcussive symptoms appears to be inversely related to injury severity, such that milder brain injuries can cause greater subjective impairments in functional cognitive status (Mittenberg, DiGuilio, Perrin, & Bass, 1992). In PCS, changes in cognitive, behavioral, and psychosocial domains tend to be subtler and less specific than those seen in more severe cases of brain injury. Research has suggested that this may be due to non-specific effects of mTBI on one's ability to employ cognitive resources, such as problem solving and regulation of emotions (Bryant, 2008). Such cognitive deficits, particularly those related to reduced processing speed, executive function inefficiency, and various somatic and psychosocial complaints, can become long lasting (Moore & Stambrook, 1995). Once developed, postconcussive sequelae have the ability to impede successful adaptation following mTBI via negative effects on physical, emotional, social, and vocational functioning (Martelli, Zasler, Nicholson, & Hart, 2001).

Although only a small subset of individuals who experience mTBI go on to develop residual symptoms associated with PCS, the sheer number of people who incur this type of injury make it a formidable problem. A meta-analytic review of the long-term neuropsychological effects of mTBI conducted by Binder, Rohling, & Larrabee (1997), found that persistent cognitive sequelae are relatively uncommon, with related impairments three months past injury falling within the range of 3-8%. However, these findings may be inaccurately low, as it is believed that the true incidence and health impact of mTBI is grossly underestimated (McCrea, 2008). This is further compounded by the fact that as many as 25% of all people with brain injuries have no contact with the health care system (McCrea, 2008). Thus, the impact of long-term symptoms in this subset of individuals should not be underestimated. In 2003, the CDC presented a report to the US Congress that described mTBI as a “silent epidemic” of which the magnitude and impact of the problem are highly underestimated (Center for Disease Control and Injury Prevention, 2003). This notion is further highlighted by the estimation that mTBI will be the third leading cause of disability worldwide by the year 2020 (Murray & Lopez, 1997).

Unlike more severe brain injuries, the subjective experiences of cognitive difficulties that result in adjustment and behavior problems are largely responsible for long-term disability rather than cognitive and neurobehavioral impairment per se (Martelli, Bender, Nicholson, 2002). Difficulties in adaptation, including psychosocial and behavioral impairments, represent the most disabling consequences resulting from cerebral insult. Following brain injury, personality and behavioral changes have been implicated as the primary obstacle to successful adaptation and community reintegration (Miller, 1986). Behavioral changes found to prevent resumption of a normal life include social withdrawal, fatigue, unusual/bizarre thought content, anxiousness, and pain-related behaviors (Stambrook, Moore, & Peters, 1990). A prospective study by Dawson and

colleagues (2004), found that brain injury residues continued to impact community integration, psychosocial functioning, and overall quality of life at both one and four years post-trauma, regardless of injury severity. Anxiety symptomology, a common after effect of mTBI, has also been implicated as a significant contributing factor in delaying return to productivity (Bond, 1984).

Economic and health care costs associated with mTBI are substantial, with lost productivity representing the largest component of economic costs associated with this type of brain trauma. Annual costs associated with the treatment of mTBI in the United States are significant, with estimates that preclude indirect costs such as lost productivity, approximating \$17 billion (Borg et al., 2004). This is largely due to the sheer volume of mTBI cases (McCrea, 2008). A prospective study conducted by Boakes and colleagues (2005), found that the majority of patients presenting at emergency departments with an mTBI did not return to work until 1-3 months post-injury. At 41%, individuals who are unemployed at the time of injury are the least likely to return to work (Dikmen, Temkin, Machamer, Holubkov, Fraser, & Winn, 1994).

### **Diagnosis & Treatment of Postconcussive Syndrome**

Modern medicine has long considered PCS to be among the most perplexing and complex neurological conditions to treat, and despite the finding that approximately 500,000 new cases of PCS are diagnosed each year in the United States, current conceptualizations of the syndrome are lacking (Cassidy, Carroll, Peloso, et al., 2004; Wood, 2004). The causes of PCS are somewhat controversial, and there has been some contention around the constellation of long term symptoms reported by those who go on to develop the syndrome following mTBI.

Ecological validity refers to the ability of clinical assessments to accurately predict functional expressions of behavior in real-life situations or contexts. In terms of less severe brain

injuries, most neuropsychological assessments lack ecological validity, as they fail to consider how numerous variables present in real-world situations influence component skills measured in a laboratory setting. As applied to mTBI, ecological validity can be improved by shifting from a biomedical model to a biopsychosocial perspective of dysfunction. Specifically, it is important to develop an understanding of the unique situational, cognitive, emotional, and social demands of a patient's life during assessment and treatment planning. The utility of test data is significantly improved if combined with an understanding of the individual's history, vulnerabilities, social support, personality, emotional status, and coping patterns (Martelli, Zasler, & McMillan, 1998).

Further complicating assessment, diagnosis, and treatment of PCS, is the inability of some standard diagnostic tests, such as computerized tomography (CT), to detect biomechanical and neurophysiological changes resulting from mTBI (Bay & McLean, 2007). Despite these difficulties, the cluster of symptoms associated with PCS is remarkably consistent, which suggests common underlying factors are involved in the syndrome's etiology and development (McMordie, 1988).

Research has suggested that mTBI may cause subtle damage to axonal and metabolic processes in the brain that result in increased vulnerability to further injury (Biasca & Maxwell, 2007). Some evidence suggests that axon damage and changes in brain metabolism resulting from biomechanical forces associated with mTBI may progress over time, causing the residual symptoms known as PCS. These changes may also be responsible for the brain's increased vulnerability to additional damage following the initial injury.

It has been proposed that stress responses centrally regulated by the brain may become dysregulated following mTBI (Bay & Liberzon, 2009). Two stress systems are thought to mediate responses to psychological stress: the hypothalamic-pituitary-adrenal (HPA) axis and the

sympathoadrenal axis (SAS). Stress-related variables identified as risk factors for developing PCS include the presence of pre- and post-injury psychosocial stressors and social difficulties (Meares et al., 2007; McCauley, Boake, Levin, Contant, & Song, 2001). It has been suggested that dysregulated stress responses, which are influenced by a myriad of psychological and neurobiological factors, may set in motion processes that ultimately lead to poor outcome and decreased adaptability following mTBI (Bay & Liberzon, 2009).

In their stress response–vulnerability model, Bay and Liberzon (2009) propose that one's stress response is a central predictor of poor outcome and adaptation following mTBI, due to the findings that psychological stress is significantly associated with residual cognitive symptoms, and such symptoms are significantly associated with functional impairment. This assertion is supported by research that suggests sustained stress after mTBI contributes to psychological distress and may be harmful to the recovering brain (McEwen, 2008). Thus, while it is likely that organic factors are involved in the onset of acute cognitive and behavioral symptoms following mTBI, psychosocial variables also likely play an important role in the development of PCS (Smith-Seemiller, Fow, Kant, & Franzen, 2003).

### **Predicting Outcome after Brain Injury**

As there is considerable variability in outcome following traumatic brain injury, identifying predictors of long-term outcome is particularly important (Dawson, Levine, Schwartz, & Stuss, 2004). A considerable amount of research has investigated the relationship between course of recovery, outcome, and pathophysiologic/neurologic variables such as loss of consciousness, post-traumatic amnesia, and locale of lesion following brain injury (Katz & Alexander, 1994). Injury severity variables, such as Glasgow Coma Scale scores and length of post-traumatic amnesia, have typically been used to predict long-term outcome after traumatic



brain injury. However, inconsistencies in the literature suggest that such factors are unreliable determinants of outcome, especially in cases of mTBI (Dawson et al., 2004). When predicting post-injury adaptation to brain injury, biopsychosocial variables must be considered in addition to injury severity factors, as research suggests that symptoms may be initiated by injury or pathological processes but persist as a result of dynamic interactions between multiple sensory, behavioral, socio-cultural, and cognitive factors that must be considered within a developmental trajectory (Martinelli, Zasler, & MacMillan, 1998).

Biopsychosocial models of adaptation that recognize brain injury as occurring within a multiaxial matrix of biological, psychological, sociocultural, and environmental factors help to explain diversity in outcomes, and are much more promising than models that place exclusive emphasis on pathophysiologic variables (Martinelli, Zasler, & MacMillan, 1998). Supporting this assertion is the research of Moore and Stambrook (1995), which suggests that cognitive beliefs and coping patterns play a substantial role in adjustment following brain injury and may explain more of the variance in outcome than injury severity variables. Satz (1993) argues that when conceptualizing outcome and adaptation following a traumatic insult to the brain, it is critical to consider the vulnerabilities and protective resources that each individual brings to their injury.

### **The Importance of Pre-Injury Status**

For TBI in general, a number of vulnerability factors influence adaptation and outcome subsequent to brain injury, including pathophysiologic and neurologic variables, injury context variables, premorbid biologic variables, premorbid and post-injury psychosocial variables, premorbid and post-injury personality and coping variables, and environmental variables (Heilbrunner, Martelli, Nicholson, & Zasler, 2002; Klonoff & Lamb, 1998; Mathias & Coats, 1999; McCrea, 2008; Mittenberg, DiGuilio, Perrin, & Bass, 1992; Paniak, Reynolds, Toller-

Lobe, Melnyk, Nagy, & Schmidt, 2002; Williams, Potter, & Ryland, 2010). However, research on outcome following brain injury has largely focused on trauma-related variables, such as duration of loss of consciousness, area of injury, and other biomedical factors, rather than examining pre-injury status. This is partially due to the difficulty of obtaining reliable pre-morbid information from TBI patients and their families (Dikmen, 1995). Following brain injury, estimation of premorbid functioning is a formidable yet important task, as variability in outcome is partially a function of pre-injury factors and characteristics such as personality, social roles, intelligence, and sociocultural influences (Martelli, Bender, Nicholson, 2002; Ruff, Mueller, & Jurica, 1996). A number of pre-injury variables have been identified as risk factors for poor outcome following mTBI, including psychiatric comorbidities, the presence of stressful life events, and increased levels of perceived stress (Bay & Bergman, 2006).

Numerous variables have a moderating effect on post-injury functioning following brain injury, including cognitive patterns and beliefs, personality, resources, medical status, and residual symptoms (Moore & Stambrook, 1995). When an individual is confronted with brain injury, premorbid personality characteristics and coping resources interact with sociocultural factors to produce complex and individualized patterns of sequelae of symptoms (Prigatano, 1986). Brain injury frequently results in a myriad of cognitive, emotional, physical, and social stressors that, both singularly and in combination, challenge one's repertoire of coping skills while at the same time undermining available resources, such as premorbid skills and social support (MacMillan, Hart, Martelli, & Zasler, 2002). Disentangling contributing factors involved in impairment, disability, and injury residua, is a formidable task that is fraught with obstacles. This is particularly true in cases of mTBI, wherein the consistency and apparent validity of medical evaluations and opinions become much more uncertain.

Kay (1992) developed a conceptual model to explain variability in outcome following TBI, which proposed that for any given individual a number of biological and psychosocial factors uniquely combine to influence the impact and outcome of brain injury. This model asserts that pre-injury variables related to personality and psychosocial factors interact with individual differences in biologic systems, such as those pertaining to neurological and hormonal functioning; the combination of which produces functional outcomes specific to the individual.

According to Kay (1992), after sustaining a concussion a myriad of psychosocial variables, including personality style, pre-existing psychological disturbance, and perceived stress levels result in individualized reactions to the injury, symptom presentation, and resulting changes in cognitive functioning. Supporting this assertion is the finding that certain premorbid personality styles are associated with increased vulnerability to poor outcome following mTBI (Kay, 1992; Ruff, Mueller, & Jurica, 1996). Vulnerable personality types reported in these studies include depressed personality styles characterized by mood fluctuations dominated by negative affect, dependent personality styles that involve an excessive need to be taken care of, and somatically-focused personality styles that involve a preoccupation with physical health and well-being (Kay, 1992). Perfectionistic or overachieving individuals may also be more vulnerable to poor adaptation following mTBI, as they are more likely to perceive post-injury impairments or changes in performance as catastrophic and have complicated recoveries characterized by greatly elevated stress levels (Ruff, Mueller, & Jurica, 1996).

There is growing appreciation that pre-injury stressors and vulnerability factors can have a substantial impact on one's ability to successfully cope and adapt to the challenges and demands experienced subsequent to brain injury (Martelli, Bender, Nicholson, & Zasler, 2002). Premorbid psychosocial variables found to influence recovery from brain injury include a history

of substance abuse, mental health status, and social involvement and support (Thomsen, 1992). A history of prior stressors that caused reactions of fear and helplessness was also found to be associated with poor outcome and adaptability following mTBI, which may be due to the cumulative effects of psychological distress and decreased coping ability (Webb, 2004). The influence of pre-existing vulnerabilities on brain injury outcome was further demonstrated by Raskin (1997), who found that individuals with a history of sexual abuse demonstrated greater degrees of impairment following mTBI than those who did not.

It has become increasingly recognized that stress contributes to the development of PCS (Ruff, 2005; Wood, 2004). Perceived stress is associated with negative outcome, including persistent psychological and physical symptoms, following mTBI (Bay & Sikorskii, 2009). Cognitive symptoms experienced as a result of mTBI may be ascribed meaning through interpretation of the context in which they occur and perceptions of one's ability to adaptively cope with related stressors. The work of Mittenberg, DiGuilio, Perrin, and Bass (1992), suggests that symptom expectations following mTBI may play an etiological role in the development of PCS, especially in cases where obvious or adequate explanations for symptoms are not available. In such cases, the patient may reattribute a variety of emotional, cognitive, and physiological symptoms to their mTBI, which was inherently stressful and activated an autonomic response. Further, cognitive residua may serve to exacerbate psychological stress as one attempts to solve problems related to new limitations while cognitive systems are functioning less efficiently (Bay & Liberzon, 2009).

### **Premorbid Mental Health Status & Psychological Distress**

Symptoms of anxiety and depression are common in the months following brain injury and coincide with a growing awareness of, and reaction to, post-injury limitations (Butler &

Satz, 1988). Development of depressive symptomology is common after all types of brain injury, regardless of severity, with varying prevalence rates. Reported estimates of depression subsequent to mTBI have been as high as 44% (Iverson, 2006). This is consistent with studies that estimate as many as 77% of individuals who sustain a brain injury, regardless of severity or type, will meet criteria for a mood disorder at some point during the recovery process (McEwen, 2008). Individuals with a history of mental disorder may be particularly vulnerable, as brain injury often worsens pre-existing psychological conditions (Moore & Stambrook, 1995).

Providing support for this notion is the finding that premorbid psychological adversity is associated with negative outcome and persistent symptoms following brain injury (Rutherford, 1989). MacMillian and colleagues (2002), found that a history of mental health problems or substance abuse was associated with poor adjustment following mTBI, as evidenced by lowered rates of employment and independent living status. Further evidence is provided by the work of Ruff, Mueller, and Jurica (1996), who found that the recoveries of mTBI patients with a history of depression were often complicated by an exacerbation of depressive symptoms and despondency. Summarizing case study data on the topic led Martelli (1998) to conclude that entrenched perceptions of victimization, anger or resentment, and concomitant depression and anxiety represent significant obstacles to optimal adaptation following brain injury.

Depression may be particularly problematic early in the recovery process, as it can contribute to or exacerbate brain injury symptoms such as cognitive changes, fatigue, emotional dysregulation, and decreased motivation (Iverson, 2006; McCauley, Boake, Levin, Contant, & Song, 2001). These effects have the potential to negatively impact adaptation and community reintegration, as depressive symptoms are associated with deterioration in social functioning and reduced participation in activities of daily living during the first year following brain injury

(Jorge, Robinson, Starkstein, & Arndt, 1994). Social withdrawal, a hallmark characteristic of depression, may further serve to impede healthy recovery, as socially isolated individuals typically demonstrate poor adaptation to subjective post-injury limitations (Webb, 1991). Individuals who maintain perceptions of victimization, particularly in regard to their health status, have also been shown to demonstrate less optimal outcomes following brain injury (Rutherford, 1989).

### **Premorbid Medical History**

In addition to psychological health, the most accurate predictors of outcome following brain injury also include consideration of a patient's premorbid medical history (Martelli, Zasler, & McMillan, 1998). Supporting this assertion is the work of Maio and colleagues (2006), who found that pre-injury health and functional status could predict PCS impairment three months post-mTBI. In a study designed to identify predictors of brain injury outcome, Dawson and colleagues (2004) found that the presence of recurrent physical ailments had a negative impact on return to productive activity following mTBI. This is consistent with the finding that individuals who report physical injury symptoms in addition to mTBI are less likely to return to work than those who do not endorse concomitant injury (Ruffolo, Friedland, Dawson, Colantonio, & Lindsay, 1999). Providing further support is the finding that injury context variables such as collateral injuries, motor function impairment, and the presence of pain, adversely affect outcome following mTBI and are associated with post-injury disability (Hawkins, 1996).

According to Ruff, Mueller, and Jurica (1996), somatically focused individuals who maintain preoccupations with physical symptoms tend to endorse "multiple premorbid physical symptoms intermixed with new or changing post-morbid residua" following mTBI (p. 41). The

increased somatic awareness associated with a history of chronic illness or pain may serve to sensitize an individual to cognitive sequelae resulting from mTBI. Hyper-focused attention to brain injury symptoms may lead to catastrophizing, increased stress, anxiety, and depression, which in turn can cause further exacerbation of both pain and mTBI symptoms. Supporting this assertion is a study by Greiffenstein and Baker (2001), which found that pre-injury MMPI-2 profiles of postconcussive patients were abnormal and predominantly characterized by somatoform symptoms and health concerns. Further, environmental variables that serve to reinforce illness behaviors, such as over solicitous attention and support, have been found to interact with certain personality traits and coping skill deficits to produce differential adaptation following brain injury and within chronic pain populations (Martelli, Zasler, & MacMillan, 1998).

### **Chronic Pain**

Acute pain is a normal sensation that is triggered within the body's nervous system following injury, or any number of pathological conditions, through a process called nociception. Typically, the nociceptive signals that occur from damage to visceral, somatic, or neural somatic structures diminish with a subsequent fading of the unpleasant sensory pain experience as the injury heals (Vanderah, 2007). Pain is deemed to be chronic when its presence persists beyond the normal time expected for resolution of the underlying physiological causes. Although comprehensive epidemiological data are not available, studies have estimated that at any given time, approximately 47% of the general population is likely coping with some type of chronic pain (Elliot, Smith, Penny, Smith, & Chambers, 1999). Niv and Devor (2006) state that secondary implications of chronic pain such as immobility effects, reliance on medication and social isolation add to the magnitude of the problem. These factors, combined with high

prevalence rates and associated social burdens, make chronic pain a major healthcare problem that deserves significant attention.

Numerous influential variables have been implicated in chronic pain etiology including catastrophizing, learned helplessness, and daily hassles, to name a few (Mercado, Carroll, Cassidy, & Cote, 2005). Severity of pain is associated with depression, poor satisfaction with life, and maladaptive avoidant coping styles (Bryant, Marosszeky, Crooks, et al., 1999). These findings suggest that pain may be initiated by injury or pathological processes but persists as a result of dynamic interactions between a multitude of factors, including sensory, behavioral, socio-cultural, and cognitive influences that must be considered within a developmental trajectory (Bursch, Walco, & Zeltzer, 1998). In recognition of this growing body of research there has been a shift in the medical community's conceptualization of chronic pain in recent years, with the number of etiological and prognostic factors potentially involved in chronic pain conditions rendering a dichotomous, organic versus nonorganic approach ineffectual (Barnett, Ledoux, Garcini, & Baker, 2009). In response to this growing realization, integration of biopsychosocial approaches to health care has led to increased collaboration between traditional medicine and psychology.

### **Psychological Components of Chronic Pain**

The enormous human and economic costs associated with chronic pain have increased interest in the psychological components of chronic pain, as there is a growing consensus that personality traits and related alterations in cognitive patterns and behaviors have important implications for health outcome. It is not unreasonable to assume that personality may have an effect on how one perceives and interprets pain, exerting influence via cognitive rather than sensory mechanisms. Tendencies to react to the initial onset of pain with negative emotionality



and fear-avoidance beliefs are related to decreased wellbeing (Fry & Debats, 2009). Indeed, studies have found strong associations between scores on the dimension of neuroticism, as measured by the NEO-Personality Inventory, and pain behavior, self-blame, and emotional disturbance (Wade, Dougherty, Hart, Rafii, & Price, 1992; Williams, Robinson, & Geisser, 1994).

Psychological variables have been found by several studies to be better predictors of adjustment to pain than physiological factors (Lumley, Kelley, & Leisen, 1997; Tan, Jensen, Thornby, & Sloan, 2008). Negative self-statements and other catastrophizing thoughts have been found to positively associate with psychological distress and pain-related interference in daily activities even after controlling for demographics, work status, and pain severity (Stroud et al., 2000). Studies have also found psychological stress and maladaptive thought patterns to be predictive of pain severity and disability (Asghari & Nicholas, 2006; Stroud, Thorn, Jensen, & Boothby, 2000).

One psychological mechanism that has recently received attention is self-efficacy. Self-efficacy refers to the extent a person believes they are capable of performing behaviors required to succeed in a situation (Asghari & Nicholas, 2001). Research investigating the affect of perceived competence on behavior suggests self-efficacy contributes to performance (Bandura, O'Leary, Barr Taylor, Gauthier, & Gossard, 1987). Evidence suggesting that lower control appraisals and self-efficacy beliefs can be predicted by "personality vulnerability" has also been cited in the literature, with one study finding that self-efficacy beliefs were negatively associated with the frequency and severity of pain-related behavior in chronic pain patients over a nine-month period (Asghari & Nicholas, 2006). Thus, it may be that certain personality traits increase vulnerability to stress and negative emotional states, predisposing one to cope with pain in less

efficacious, more maladaptive ways that exacerbate health problems. This notion is further supported by the finding of Carroll and colleagues (2002), that the tendency to engage in particular types of coping strategies is predictive of subsequent health adjustment and functioning.

Self-efficacy appears to play a mediating role in adjustment to chronic pain (Arnstein, Caudill, Mandle, Norris, & Beasley, 1999; Arnstein, 2000). It has been suggested that negative pain-related cognitions serve to lower beliefs regarding self-efficacy as well as to increase the likelihood of engaging in passive, maladaptive coping strategies (Jensen, Turner, & Romano, 1991; Turner, Jensen, & Romano, 2000). Passive coping strategies such as catastrophizing, wishful thinking, learned helplessness, and negative thinking have been found to associate with poor adjustment and to predict negative health outcome in chronic pain populations (Harkapaa, 1991; Grossi, Soares, & Lundberg, 2000). Results of a longitudinal study by Mercado and colleagues (2005) suggested engagement in passive coping strategies substantially increased the risk of developing debilitating low back pain in the general population, regardless of extraneous variables such as socioeconomic status, demographics, and general level of health.

The notion that perceptions of one's ability to manage chronic pain and to effectively engage in adaptive health behaviors predict pain-related disability has been replicated in the research (Stroud, Thorn, Jensen, & Booth, 2000). This finding has been supported by the research of Arnstein (2000), who found that self-efficacy beliefs accounted for more of the variance in pain-related disability than pain intensity, another significant mediator of chronic pain. Results from a related study found that self-efficacy accounted for 44% of the explained variance in pain-related disability in patients receiving treatment for chronic pain at an outpatient pain clinic (Arnstein et al., 1999). Evidence that self-efficacy beliefs are responsible for a

significant amount of the explained variance in maladaptive behaviors associated with pain lends credibility to the hypothesis that such beliefs likely play a substantial role in the development and maintenance of chronic pain (Asghari & Nicholas, 2001).

The notion that psychological processes have ramifications for physical health is not a new concept. Such speculations were reported as early as the times of Hippocrates, who linked psychological distress and disease with the hypothesis that imbalances in the four bodily humors (black bile, phlegm, blood, and yellow bile) were responsible for chronic emotional states (Merenda, 1987). The physiological basis of stress was first defined in 1936 by Hans Selye, who posited that the state involved co-activation of sympathoadrenomedullary system and the limbic-hypothalamic-pituitary-adrenal axis (HPA) (Chrousos, 1995). Recognition of the substantial comorbidity of psychological and physical disorders in subsequent years has led to increased awareness of the physiological consequences of negative emotional experiences (Salovey, Detweiler, Steward, & Bedell, 2000). However, despite a large body of research investigating the relationship between psychological functioning and health, our understanding of the mechanisms underlying such associations is still quite limited.

In an attempt to delineate mediating constituents and increase our overall understanding of implicated factors, various theories have been developed and utilized in health psychology that seek to explain how psychological experience may affect physical well-being (Watson & Pennebaker, 1989). One factor commonly incorporated into such theories that has received substantial support is the presence of negative affectivity (NA), a general dimension of distress that Costa & McCrae (1987) define as “a broad dimension of individual differences in the tendency to experience negative, distressing emotions and to possess associated behavioral and cognitive traits” (p. 301). A wide range of adverse emotional states are subsumed within the NA

factor including anxiety, shame, guilt, and depression. NA can be assessed as either an emotional state, which refers to transient fluctuations in mood, or as a trait, which refers to a stable predisposition to experience negative affect and to maintain corresponding cognitive and behavioral styles (Watson & Clark, 1984).

It has long been hypothesized that negative or adverse emotional experiences have a detrimental effect on physiological functioning and overall physical health, however only recently have technological advances provided the opportunity to directly test such propositions (Polk, Cohen, Doyle, Skoner, & Kirschbaum, 2005). Over the past 25 years numerous studies have provided evidence that emotional disturbance and psychological stress can instigate disruptive changes in the immune system via communication between the central nervous system and the endocrine system (Reiche, Nunes, & Morimoto, 2004). Recent research has suggested that the stress-induced activation of, and interactions between, such stress-response systems can produce alterations in concentrations of circulating hormones that diminish immune system functioning, ultimately increasing one's susceptibility to illness (Polk, Cohen, Doyle, Skoner, & Kirschbaum, 2005). Differences in the way one tends to perceive and react to stimuli have been demonstrated to instigate different immune responses that are likely mediated by neuroendocrine mechanisms (Segerstrom, 2000). The ramifications of disturbances to stress-response systems caused by negative emotional states are numerous, with studies linking them to infectious disease, cardiovascular dysfunction, cancer, autoimmune disorders, wound healing, and chronic inflammatory conditions (Cohen & Rodriguez, 1995; Friedman, 1992; Kiecolt-Glaser, McGuire, Robles, & Glaser, 2002; Palermo-Neto, Massoco, & Souza, 2003).

## **Financial Incentives & Litigation**

The role financial incentives play in the development and maintenance of symptom-related disability after mTBI has been a hotly contested issue for the past century (McCrea, 2008). As postconcussive symptoms are subjective, and are generally considered to largely be the result of psychological and psychosocial factors, it is not surprising that considerable attention has been paid to the role of financial incentives and secondary gain in cases of persistent functional disability. The effects of medico-legal compensation, such as Social Security Disability application, insurance policy coverage, personal injury litigation, and Workers Compensation claims, on the development of PCS and functional disability after mTBI have received increasing attention over the past decade (Martelli, Zasler, Nicholson, & Heilbronner, 2001). According to Martelli and colleagues (2001), the effects of response bias, as defined by conscious and unconscious behaviors that reflect symptom report and presentation that is less than fully truthful or accurate, represent a critical element that must be considered for valid assessment to occur following physical and neurologic injuries. Failure of tests designed to assess effort during neuropsychological test performance is common among adult PCS patients seeking financial compensation, with reported failure rates as high as 40% within this group (Green, Flaro, & Courtney, 2009).

The impact of financial incentive on outcome after mTBI was highlighted by a meta-analytic review conducted by Binder and Rohling (1996), which found a moderate overall effect size (0.47) between the two variables. Late-onset of symptoms was particularly prevalent among patients seeking monetary compensation. Their results also suggested that monetary incentive had a greater effect on prognosis in cases of mTBI than more severe closed head injuries. In response to these findings, the authors emphasized the importance of considering financial

incentive and assessing motivation during clinical evaluation of subjective functional disability after milder brain injuries, especially when there has been little or no loss of consciousness along with normal neuroimaging results. Iverson and colleagues (2006) also summarized the effects of financial incentive and litigation stress on the development and maintenance of PCS symptomology, concluding that:

Exaggeration is very common in people believed to have a persistent postconcussive disorder who are being evaluated in relation to Workers Compensation claim, disability evaluation, or personal injury litigation.

Malingering is much less common than exaggeration, and it would be a mistake to assume, without careful deliberation, that the exaggeration reflects malingering.

(p 402)

Although the majority of postconcussive patients involved in litigation may not be consciously malingering, exaggeration of symptoms is a noteworthy problem nonetheless, regardless of whether it is consciously feigned or due to unconscious somatization factors (Martelli, Zasler, Hart, Nicholson, & Heilbronner, 2003).

Some have argued that solely concentrating on the monetary aspects of litigation oversimplifies the problem by failing to consider other influential factors inherent to the financial compensation process (Tyndel & Egit, 1988). The vast majority of studies in this area have focused on examinee exaggeration of impairments, and fail to consider the influence of examiner response bias and possible incentives to minimize true deficits or functional disability (Johnson, Krafka, & Cecil, 2000). When inconsistencies in presentation or neuropsychological assessment results are present, health professionals often exhibit personal predispositions in determining whether symptoms are caused by neurological dysfunction, due to motivational factors, or are

the result of secondary psychosocial influences (Heilbrunner, Martelli, Nicholson, & Zasler, 2002).

Proponents of this position also argue that effects of “nomogenic disorders,” defined as psychological disorders that are developed, exacerbated, or perpetuated by legal proceedings and applications of the law, are minimized in the majority of studies investigating the relationship between PCS and financial compensation. Supporting this assertion is a study by Martelli and colleagues (1999), who found that insurance resistance and delays in authorizing treatment or paying medical bills was associated with maladaptive post-injury adjustment. The results of a longitudinal study investigating the relationship between financial compensation and symptoms after mTBI suggested that the association between compensation seeking and greater symptom report persists over time (Paniak, Reynolds, Toller-Lobe, Melnyk, Nagy, & Schmidt, 2002). The negative effects of adversarial medico-legal proceedings was further illustrated by a study that followed a large sample of litigants, which found that the majority of participants had failed to return to work two years post-settlement (Mendleson, 1995). Though symptom exaggeration and malingering should always be considered in evaluation PCS, the negative effects of litigation-related stress on psychological and physical wellbeing should also be taken into consideration.

Originally coined “compensation neurosis,” symptoms that are now referred to as postconcussive syndrome were once believed to resolve after settlement of litigation proceedings (Binder & Rohling, 1996). However, findings that document the persistence of symptoms after claim settlement, or in the absence of litigation, imply that financial incentives alone are insufficient in explaining PCS and suggest other factors are involved. Although the need to consider possible secondary gain as an influential force in PCS has clearly been demonstrated, the use of objective clinical judgment cannot be underestimated in the assessment process. As

informative as current neuropsychological instruments may be, they are far from infallible and one must take care to consider the potentially large number of false negatives that often accompany standard cut-off scores (Martelli, Zasler, Bender, & Nicholson, 2003; Roskes, 1997).

### **Effects of Chronic Pain on Cognitive Functioning**

Cognitive impairment can occur as a result of both biomechanical injury and psychological trauma, the latter of which may result from chronic pain that is perceived to be uncontrollable or unmanageable (Stein & McAllister, 2009). Though there has been considerable variability in outcome across studies, a number of functional neuroimaging investigations have indicated that chronic pain has the ability to disrupt brain processes (Cote & Moldofsky, 1997; Doscha, Clark, Morasco, Freeman, Campbell, & Helfand, 2009; Martelli, Grayson, & Zasler, 1999; Smith-Seemiller, Fow, Kant, & Franzen, 2003). Further supporting this assertion is the finding that abnormal single-photon emission computed tomography (SPECT) results, which provide high resolution 3D images of brain structures, are often found in individuals suffering from a variety of chronic pain syndromes (Martelli, Grayson, & Zasler, 1999). Studies investigating the relationship between pain and cognitive impairment have implicated pain-related problems, such as mood disturbance, fatigue, and increased somatic awareness, as contributing to functional disability (Hart, Martelli, & Zasler, 2000).

It does not seem unreasonable that chronic pain has the ability to impair cognitive processes, as it constitutes a significant stressor that can lead to feelings of hopelessness, anxiety, somatic hypervigilance, and negative beliefs and attributions regarding one's ability to cope. The mood disturbances and unremitting stress that frequently accompany chronic pain often lead to restricted participation in daily activities, a perceived loss of control, and diminished reinforcement, which have a resulting impact on one's sense of self-efficacy and personal



identity (Hart, Wade, & Martelli, 2003). Further, the interpersonal effects of brain injury and chronic pain are similar, in that both place a great deal of stress on the family, or primary support system (Moore & Stambrook, 1995). In both cases, strained relationships and impaired communication of needs may contribute to feelings of low personal control and helplessness. Avoidant behavior, increased social isolation, and reductions in activity level can perpetuate a cyclic pattern of disability-enhancing behavior that serves to increase emotional distress and symptom-related impairment. The negative physiologic correlates of chronic stress may manifest as symptoms typical of illness, such as fatigue, muscle tension, and sleep disturbance, which then contribute to psychological distress in a vicious cycle (Hart, Wade, & Martelli, 2003).

Pain is frequently reported following mTBI. In a systematic review of the literature, Nampiarampil (2008) reported that approximately 75% of PCS patients endorsed symptoms of chronic pain after sustaining an mTBI, prevalence rates which are significantly higher than rates of chronic pain syndromes associated with moderate to severe traumatic brain injuries (Lahz & Bryant, 1996). As a result, it is not uncommon for brain injury specialists to misdiagnose chronic pain sequelae for postconcussive symptoms, misattribution of symptoms which serves to amplify functional disability and increase long-term healthcare costs. This is not surprising considering the neuropsychological test results of chronic pain patients are similar in many respects to those produced by mTBI (Martelli, Zasler, Nicholson, & Hart, 1999). Increased somatic awareness and psychological factors associated with chronic pain, such as emotional suffering, maladaptive illness-related beliefs, and resulting lifestyle disruption, may be responsible for the resulting detrimental effects on cognitive performance (Nicholson, 2000). One study that reviewed the literature on pain, cognition, and mTBI indicated that chronic pain is as significant, if not more so, as brain injury sequelae in determining neuropsychological

impairment (Nicholson, 2000). Given these findings, Martelli, Zasler, Nicholson, & Hart (2001) argue that the presence of pain and pain-related symptoms must be considered as possible contributory factors in the treatment of putative mTBI.

Neuropsychological test performance appears to have an inverse relationship with somatic focus and associated complaints (Eccleston et al., 1997). Cognitive deficits have consistently been found among chronic pain patients who experience psychological distress associated with heightened somatic awareness and preoccupation. Indeed, studies suggest that the emotional and psychosocial responses to prolonged pain have a disruptive influence on cognitive processes (Cote & Moldofsky, 1997). Supporting this notion is a study by Iezzi et al. (1999), which found that high levels of psychological distress resulting from chronic musculoskeletal pain was associated with deficits in attention, memory, processing speed, and executive functions. Tests of psychomotor speed also appear to be particularly sensitive to the disruptive effects of chronic pain (Hart, Martelli, & Zasler, 2000).

Concomitant pain appears to complicate the presentation and recovery of brain injury patients, as the presence of pain and symptoms secondary to physical injuries have been shown to interfere with cognitive functioning and to produce related impairment (Sbordone & Purisch, 1996). Providing further support is research investigating the effects of posttraumatic headache, a phenomenon commonly experienced after brain injury. It has been reported that as many as 70% of PCS patients experience posttraumatic headache (Zasler, 2011). Such studies indicate that pre-existing headache syndromes are often exacerbated by brain injury. Not surprisingly, a worsening of such premorbid pain conditions is associated with increased impairment and suboptimal recovery following mTBI (Jensen & Nielsen, 1990; Landy, 1998). Post-traumatic headache is associated with suboptimal neuropsychological test performance and deficits in

complex attention, information processing speed, cognitive flexibility, and verbal fluency. Secondary deficits in memory and learning have also been reported (Martelli, Grayson, & Zasler, 1999).

Symptoms that often accompany chronic pain, such as depressed mood, increased psychosocial stress, sleep disturbance, and excessive fatigue, have been shown to negatively affect cognitive performance and may interact with brain injury sequelae to increase functional impairment (Martelli, Zasler, Nicholson, & Hart, 2001). In fact, some have argued that pain-related mood disturbance, fatigue, and lifestyle interference secondary to disability, have a greater impact on cognitive functioning than pain severity or pain location (Hart, Wade, & Martelli, 2003). Given these findings, it does not seem unreasonable to assume that premorbid chronic pain would be particularly detrimental to adaptation following mTBI as it may result in greater reactive symptom distress; the stress associated with additional neurologic symptoms may further impede adaptive coping efforts, which in turn would serve to exacerbate or perpetuate functional impairment.

### **Diathesis-Stress Models**

An ample body of research suggests that pre-existing stressors and vulnerability factors have a significant influence on adaptation and outcome following injury (Greiffenstein & Baker, 2001; Kay, 1992; MacMillan, Harts, Martelli, & Zasler, 2002; Ruff, Mueller, & Jurica, 1996; Raskin, 1997). Self-efficacy beliefs related to coping, and one's ability to master demands and stressors, are expected to influence responses to physical and emotional trauma (Lazarus & Folkman, 1984). After brain injury, it seems reasonable to assume that an individual's premorbid coping skills and tendencies would serve to mediate adaptation to related symptoms and limitations.

According to diathesis-stress models, behavior can be explained as a result of biological vulnerabilities or predispositions interacting with the external environment and stressful life events (Asghari & Nicolas, 2006). As applied to functional disability, diathesis-stress models can be used to explain symptoms that seem disproportional to physical trauma, such as PCS-related impairment following mTBI (Greiffenstein & Baker, 2001). According to these models, pre-injury variables have an effect on one's ability to cope with trauma-related symptoms, such that an individual may respond differently than what would be expected to post-injury symptoms or stressors (Kay, Newman, Cavallo, & Ezrachi, 1992).

According to stress, coping, and vulnerability formulations, brain injury results in significant cognitive, social, emotional, and physical stressors that challenge the coping capacities of the individual while at the same time having the potential to diminish available resources, such as pre-injury skills and supports (Martelli, Zasler, & MacMillan, 1998). The complex interaction of factors related to one's personal history, premorbid levels of functioning, injury-related variables, and post-injury environment combine to influence adaptability and outcome (Martelli, Bender, Nicholson, & Zasler, 2002). The existence of premorbid self-defeating belief systems may be particularly vulnerable following brain injury, as even mild cognitive limitations further impede an understanding of how problematic, self-limiting behaviors and emotions contribute to negative consequences. As stated by Moore & Stambrook (1995), "the patient may not have the cognitive abilities, either in terms of... self-control or the ability to determine antecedents of consequences in his or her world to allow the individual to effectively act upon the environment" (p. 118).

It is reasonable to assume that when faced with brain injury, a person's premorbid coping characteristics become engaged, and research suggests that high levels of psychosocial stress

resulting from impaired coping and social difficulties contribute to the development of persistent symptoms following mTBI (Martelli, Zasler, & MacMillan, 1998). Self-limiting cognitive belief symptoms may develop as a result of both brain injury and chronic pain, as patients attempt to account for changes caused by their resulting health status. Such maladaptive beliefs are typically characterized by an external locus of control, feelings of helplessness, and suboptimal coping behaviors and strategies.

In their biopsychosocial model of chronic pain, McLean and colleagues (2005) propose that physical and emotional trauma activate central stress systems that subsequently trigger one of two biobehavioral response pathways: a resiliency pathway that results in more positive outcomes, or a vulnerability-stress pathway that can result in chronic impairment and dysfunctional behavioral alterations. The authors suggest that following physical trauma, the physiological stress responses of an individual are able to predict future symptoms of pain-related disability. Bay and Liberzon (2009), later adapted this model to mTBI and suggested that stress responses triggered by concussive injury interact with pre-morbid characteristics such as demographics, stressful life events, and medical and psychological comorbidities, to influence functional status and overall outcome. In other words, they assert that premorbid factors influence reactionary psychological stress responses following brain injury, which then serve to activate neurobiological events that result in functional impairment. Supporting this notion is the finding that a history of trauma or the presence of stressful life events prior to injury is predictive of poor outcome following mTBI (Ponsford et al., 2000).

In his stress and coping formulation of adaptation following brain injury, Montgomery (1995) similarly proposed that neuropsychological deficits combine with personal factors such as negative thinking, tension-arousal, fatigue, and physical symptoms, and situational factors such

as demands for complex attention, rapid processing, and external distractions, to produce impairment and functional disability. Supporting Montgomery's multi-factor theory of disability after brain injury is the work of Moore and Stambrook (1992), who found that post-injury coping strategies predicted outcome following mTBI. This research suggests that increased self-efficacy, a low external locus of control, and use of positive reappraisal coping strategies are associated with lower levels of mood disturbance and physical impairment.

Also emphasizing the role of premorbid personality characteristics, coping resources, and sociocultural factors is the work of Taylor (1983), who proposed a cognitive adaptation model for coping with traumatic stressors, such as chronic pain and brain injury. This model suggests that pre-injury factors greatly influence one's ability to find meaning in their injury, to regain a sense of mastery over residual symptoms and life in general, and to restore self-efficacy and a sense of personal identity. These conceptualizations are consistent with the literature on stress and coping, which view coping as cognitive and behavioral efforts to master demands, stressors, and conflicts (Lazarus & Folkman, 1984). Coping models of adaptation propose that when stress is experienced, individuals mobilize perceived resources in order to alter the source of the stressor and to manage negative psychological aftereffects (Lazarus, 1993).

The Cognitive Theory of Psychological Stress and Coping developed by Lazarus and Folkman (1984), suggests that the relation between stressful environmental events and outcome is mediated by cognitive appraisal processes and coping. The authors define coping as, "constantly changing cognitive and behavioral efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person" (p. 141). A related construct is attributional style, which refers to how one tends to appraise a stressor in

terms of its stability, the pervasiveness of its effects, and whether its source is internally or externally based (Abramson, Seligman, & Teasdale, 1978).

The functional impact of both mTBI symptoms and chronic pain is related to the meaning and resulting implications ascribed by an individual (Hart, Wade, & Martelli, 2003). Research on coping constructs, attributional style, and locus of control have been studied with respect to a host of physical stressors, including brain injury and chronic pain, and consistently demonstrate a link between cognitive beliefs and adjustment to health problems (Crisson & Keefe, 1988; Moore & Stambrook, 1995). These studies suggest that the beliefs and attitudes one develops in response to an injury, and one's perceived ability to successfully cope, are powerful determinants of recovery.

According to biopsychosocial stress and coping formulations, post-injury adaptation is a function of injury-related stressors and demands interacting with available coping resources (Martelli, Zasler, Bender, & Nicholson, 2004). Pre-injury coping liabilities, risk factors or vulnerabilities that serve to undermine healthy adaptation, help explain the dramatic differences in outcome and variability in disability demonstrated by those who have sustained similar injuries. The way one responds to the constellation of neuropsychological symptoms that may result from brain injury can cause changes in cognitive beliefs about personal control and self-efficacy that induce or exacerbate learned helplessness. Following cerebral trauma, individuals with pre-existing psychoemotional problems are more likely to demonstrate greater functional disability than would be expected based on the severity of their injury, behaviors that may serve to elicit acknowledgment of distress from others, increase social support, or to exert a plea for help (Heilbrunner, Martelli, Nicholson, & Zasler, 2002; MacMillan, Martelli, & Zasler, 2002; Mathias & Coats, 1998). Further, individuals may perceive their brain injury as confirmation of

helplessness, which promotes using an external locus of control (Martelli, Zasler, & McMillan, 1998; Mittenberg, DiGuilio, Perrin, & Bass, 1992).

Chronic pain has a detrimental impact on self-efficacy, beliefs that may be further entrenched when negative outcomes are experienced after unsuccessful management of mTBI symptoms (Kit, Mateer, & Graves, 2007; Martelli & Nicholson, 2011; Martelli, Zasler, Bender, & Nicholson, 2004). Maladaptive beliefs and coping patterns developed as a result of premorbid chronic pain may further limit the extent one feels able to utilize strengths to compensate for and overcome deficits following mTBI. Thus, the presence of new neuropsychological deficits caused by mTBI may interact with and accentuate maladaptive cognitive beliefs developed as a result of chronic pain. For those with premorbid chronic pain, mTBI sequelae may exacerbate these pre-existing cognitive dynamics in an attempt to explain new symptoms, further reinforcing the maladaptive belief systems that perpetuate the negative cycle. Perceived changes following mTBI may then serve to accelerate a downward spiral of depression and helplessness.

The presence of pre-injury chronic pain may serve to increase anxiety about illness and bias selective attention toward one's internal state of health. One's perceived ability to cope with physical symptoms may be impeded by anxiety and pre-existing catastrophic interpretations of pain (Nampiarampil, 2008). Further, patients may not have the ability to employ some cognitive strategies following mTBI, which further compounds the problem. Maladaptive beliefs and negative thoughts regarding perceived lifestyle interference, and reinforcement of pain behaviors, appear to contribute to pain-related suffering and may serve to further predispose one toward somatic preoccupation (Iezzi, et al., 1999). This, along with an already eroded belief in personal invulnerability and one's ability to cope, may couple with the situational stress of an mTBI and increase the likelihood that PCS will develop.



## **Cognitive Reserve Capacity**

There is substantial clinical heterogeneity in symptom sequelae resulting from mTBI. The concepts of brain reserve and cognitive reserve are theoretical constructs posited to act as potential buffers against cerebral insult, and have been used to explain the differing effects similar brain damage has on clinical outcome (Satz, Cole, Hardy, & Rassovsky, 2011). Brain reserve, which refers to the brain's physiological resilience to neuropathological damage, and cognitive reserve, which refers to one's cognitive capacity to compensate for brain damage via recruitment and use of alternate neural networks, have been used to account for differences in symptom severity following brain injury (Satz, 1993; Satz, Cole, Hardy, & Rassovsky, 2011).

Cognitive reserve capacity has been used to explain threshold differences in the expression of clinical symptoms or level of impairment and disability following central nervous system insult (Nithianantharajah & Hannan, 2009; Stern, 2002). When conceptualizing outcome according to theories of cognitive reserve capacity, a "demand versus resources" model is employed, wherein premorbid psychosocial and coping resources that serve to enhance adaptation are weighted against the demands associated with brain injury (Satz, 1993). As each individual will inherently bring a unique history and set of resources to the injury, variability in outcome and adaptation should be expected.

According to these theoretical models, individuals possess adaptational reserve for meeting demands, with greater amounts of reserve being associated with higher levels of resilience and improved adaptation following neurologic trauma (Satz, Cole, Hardy, & Rassovsky, 2011). Diminished or depleted cognitive capacity results in a lowered threshold for the expression of clinical symptoms and an increase in symptom expression or functional disability (Stern, 2002). Alternatively, greater degrees of cognitive reserve would be associated

with increased resilience and improved adaptation. To the extent that adaptational reserve is limited or previously depleted, individuals can be expected to demonstrate increased vulnerability to stressors and demands associated with brain injury and to demonstrate suboptimal recovery (Martelli, Zasler, & McMillan, 1998).

The idea of cognitive reserve is consistent with stress and coping literature, which suggests that when faced with a stressor or perceived challenge, individuals mobilize internal resources (Lazarus, 1993). It seems likely that premorbid chronic pain and related problems such as depression, fatigue, and sleep disturbance, have the potential to diminish cognitive reserve, as they represent significant and unremitting sources of stress. In this way, the presence of premorbid chronic pain may constitute a formidable vulnerability factor in the development of longstanding symptoms and poor adaptation following mTBI. Supporting this assertion are the findings of Middleboe, Birket-Smith, Andersen, and Friis (1992), who suggest that the maintenance, exacerbation, or severity of pain syndromes contributes to a process of central sensitization associated with psychological factors or pre-existing vulnerability to brain injury. Roe et al. (2001), found that on average pain patients reported greater levels of perceived stress during neuropsychological testing than subjects in a control group, which suggests that chronic pain may deplete cerebral resources and exaggerate cognitive demands. Symptoms following mTBI may have a cumulative effect in those with premorbid chronic pain, exaggerating perceptions of helplessness and victimization, and serving to promulgate or magnify cognitive impairment.

It does not seem unreasonable to assume that the premorbid coping vulnerabilities associated with chronic pain symptomology play a predominant role in mediating the impact of cognitive impairments following mTBI. Conceptualizing adaptation from a multi-factorial

biopsychosocial model that includes collective consideration of cognitive reserve, premorbid factors, and post-injury variables, has strong implications for our understanding of the impact of injury and outcome following mTBI. Supporting this assertion is a study by Martelli, Zasler, and McMillan (1998), which found that including variables related to premorbid neurological status and psychiatric status, estimated premorbid IQ, marital/relationship status, collateral injuries, and accident victimization perception, in combination, allowed successful prediction of vocational functioning and disability status following brain injury.

Variability in outcome following mTBI is not well understood (Martelli, Bender, Nicholson, & Zasler, 2002). This is particularly true for PCS, as our understanding of contributory biological and psychosocial factors is limited. On the basis of a significant amount of research denoting connections between pre-injury factors, coping liabilities, and adaptation following mTBI, it is not unreasonable to suggest that premorbid chronic pain might well be associated with PCS. Despite strong support for the association of pre-injury variables with adaptation and outcome following brain injury, research continues to be largely focused on trauma-related variables and other biomedical factors rather than examining the influence of pre-injury status. Further compounding the problem is the exclusion of individuals who have a history of mental health disorders from the majority of studies investigating outcome following brain injury (Johnston & Hall, 1994). Those with a history of substance abuse, which is often indicative of limited pre-injury coping skills and psychological vulnerability, are also often excluded from studies (Corrigan, 1995). This is problematic, as pre-injury factors and coping liabilities are now believed to play a substantial role in explaining variability in adaptation to disability and outcome following brain injury. Further, outcome studies have largely employed measures of gross physical and cognitive status rather than assessing general adaptation to

disability following brain injury and quality of life. This is problematic, as evidence suggests that behavioral and psychosocial sequelae, rather than physical impairment, represent the most disabling consequences of TBI for many individuals (MacMillan, Hart, Martelli, & Zasler, 2002).

Despite a growing appreciation for premorbid differences and coping liabilities that likely contribute to variability in outcome following brain injury, few empirical studies have sought to explore factors underlying such variability. Identification of pre-injury risk factors associated with poor outcome and adaptability following mild brain injury would help target at-risk individuals for more intensive or specialized treatment interventions. A greater appreciation and understanding of how vulnerability, stress, and coping factors contribute to adaptation subsequent to brain injury is required before intervention strategies that optimize functional capabilities can be developed.

Chronic pain affects a substantial proportion of individuals in our population. In the evaluation and treatment of mTBI the presence and effects of pain, especially pre-existing chronic pain and associated symptomology, may be overlooked or minimized. This significant stressor has been shown to drastically affect self-efficacy beliefs and perceived coping abilities, which in turn are associated with psychological distress and poor health outcome (Arnstein, Caudill, Mandle, Norris, & Beasley, 1999; Asghari & Nicholas, 2006). While numerous studies have examined the effects of injury-related or post-injury pain on neuropsychological test performance and functional disability, few have considered the affects of premorbid chronic pain on adaptation and outcome following cerebral trauma (Martelli, Grayson, & Zasler, 1999; Keidel & Diener, 1997; Nicholson, 2000).

If premorbid chronic pain is associated with poor adaptation following mTBI and PCS, thorough assessment and consideration of related information could be used to identify individuals with high vulnerability for poor outcome, and to target treatment efforts and interventions based on vulnerability areas. Such information, which contributes to a more thorough understanding of the biopsychosocial factors affecting adaptation following mild brain injury, may have the potential to enhance rehabilitation outcomes and minimize long-term disability. Early screening and treatment of chronic pain symptomology may decrease the morbidity that pain syndromes additionally impose following mTBI. Increased recognition of the effects of potentially confounding pre-injury variables, such as chronic pain, on symptoms following mTBI could minimize unnecessary healthcare costs, inappropriate treatment, and poor outcomes following intervention that may promulgate helplessness and unnecessary chronic disability.

Increased understanding of the factors that mediate the relationship between adaptation and impairment following mTBI is required in order to identify ‘at risk’ individuals, improve intervention strategies, and optimize functional capabilities in this patient population. The aim of the present study is to explore differences in adaptability after concussion between those with and without premorbid chronic pain, in an effort to enhance our understanding of factors that are associated with the functional expression of impairment, disability, and variability in adaptation following mTBI.

### Hypotheses

1. Premorbid chronic pain lowers adaptability to mTBI, as measured by the Mayo-Portland Adaptability Inventory (MPAI-4). In the proposed study, it was hypothesized that postconcussive patients with a history of premorbid chronic pain would receive

significantly higher scores on MPAI-4 at initial evaluation than those without a history of premorbid chronic pain.

2. Premorbid chronic pain has a negative effect on adaptability and resumption of societal roles over time following mTBI, as measured by mean group differences on the MPAI-4. Specifically, it was hypothesized that postconcussive patients with a history of premorbid chronic pain would demonstrate less improvement in adaptability over time than those without a history of premorbid chronic pain, as measured by mean differences in MPAI-4 scores obtained at initial evaluation and treatment discharge.
3. Consistent with the literature, it was hypothesized that postconcussive patients with a history of clinically significant psychological distress, as evidenced by diagnosis of a mental health disorder, prescribed use of psychotropic medication for psychiatric purposes, or participation in psychological services prior to injury, would endorse greater overall impairment on the MPAI-4 following mTBI than those who did not.
4. Consistent with literature suggesting a relationship between postconcussive sequelae and a pre-injury history of adverse somatic symptoms, it was hypothesized that the presence of premorbid chronic health problems would be associated with lowered adaptability and greater subjective impairment following mTBI in a sample of postconcussive patients, as measured by the MPAI-4.
5. Consistent with research documenting an association between response bias and post-injury symptom report, it was hypothesized that postconcussive patients involved in current or pending medico-legal proceedings that involve financial incentive, i.e. injury-related litigation and Workers Compensation claims, would endorse greater overall

impairment on the MPAT-4 following mTBI than those who were not involved in such proceedings.

## METHODS

### Design

This was an archival study comparing postconcussive patients with and without a history of premorbid chronic pain, psychological distress, chronic health problems, and involvement in medico-legal proceedings in terms of adaptability following mTBI.

### Participants

Participants for this study included patients who consented to, and obtained, comprehensive treatment of mTBI at the Brain Injury and Rehabilitation Center (BIRC) in Portland, Oregon. All patients were referred by an attending physician or health insurance provider for an initial evaluation and subsequent day-treatment at BIRC. Prior to evaluation and treatment, all participants provided authorization to obtain and use protected health information for research. For the purposes of this study, participants included all patients who received a diagnosis of postconcussive disorder subsequent to mTBI during or prior to the initial evaluation, as noted in their comprehensive Initial Evaluation Report.

Of the 77 subjects who presented for rehabilitation of postconcussive sequelae secondary to mTBI, 59 provided complete sets of data, which were reviewed and analyzed for the purposes of this quasi-experimental research study. The majority of these subjects were between the ages of 35-44 ( $n = 20$ , 33.9%) and were high school graduates ( $n = 22$ , 37.3%). The sample was primarily female ( $n = 35$ , 59.3%) and Caucasian ( $n = 49$ , 83.1%). Table 1 provides additional descriptive information related to the participant sample.



Table 1

*Descriptive Statistics of Participant Sample (n = 59)*

Variable	Total in sample ( <i>n</i> )	Percentage in sample (%)
1. Gender		
Female	35	59.3
Male	24	40.7
2. Age		
17 – 24	3	5.1
25 – 34	6	10.2
35 – 44	20	33.9
45 – 54	18	30.5
55 – 64	9	15.3
65 – 74	3	5.1
3. Race/Ethnicity		
White/Caucasian	49	83.1
Hispanic/Latino/a	3	5.1
Native American	3	5.1
Asian/Pacific Islander	2	3.4
Middle Eastern/East Indian	2	3.4
4. Marital Status		
Single	7	11.9
Married	33	55.9
Widowed	3	5.1
Domestic partnership	5	8.5
Divorced/separated	6	10.2
Same sex partnership	5	8.5
5. Highest level of education received		
Elementary school	2	3.4
High school/GED	22	37.3
Trade school	10	16.9
College/Associate's Degree	15	25.4
Graduate school	10	16.9

According to a review of medical records, 20 (33.9%) of the 59 subjects included in this study reported a brief loss of consciousness at the time of injury. Of those presenting for rehabilitation of postconcussive sequelae, 50 (84.8%) underwent diagnostic neuroimaging to assess for structural brain damage, with all results falling within normal limits. The remaining 9 (15.3%) subjects did not undergo neuroimaging at the time of their injury. Only six Glasgow Coma Scale scores were documented in the medical records, all of which were recorded as 15. Twelve (20.3%) subjects had a history of prior mTBI.

Motor vehicle collisions represented the most common mechanism of injury ( $n = 22$ , 37.3%), followed by falls ( $n = 20$ , 33.9%), blows to the head ( $n = 13$ , 22.0%), and assaults ( $n = 4$ , 6.8%). Slightly under half of subjects ( $n = 29$ , 49.2%) whose information was reviewed for the purposes of this study sustained work-related injuries, with over a third of participants receiving time loss or Workers Compensation wages at the time of their initial evaluation ( $n = 22$ , 37.3%).

According to a review of patient information, 36 subjects (61.0%) included in this study met criteria for premorbid chronic pain, and 40 individuals (67.8%) had a history of clinically significant psychological distress. Thirty-three individuals (55.9%) were identified as having a premorbid chronic health condition associated with a high likelihood of illness intrusiveness, i.e. illness-induced disruptions to lifestyle that compromise one's quality of life (Devins, 1994). Of these 33 subjects, 32 (97.0%) carried at least one premorbid medical diagnosis commonly associated with persistent pain, such as fibromyalgia or degenerative disc disease, which represents a potentially significant confound and major limitation of this archival research study. Table 2 provides additional information regarding the overlap between premorbid chronic pain, health conditions, and clinically significant psychological distress. Please see the Results section for further discussion of chronic health conditions included for the purposes of this study.

Table 2

*Overlap between Premorbid Chronic Pain, Chronic Health Conditions, and Psychological Distress (n =59)*

	Total (n)	Percentage in sample (%)
1. Chronic Health Condition (CHC)	33	55.9
2. CHC + Premorbid Chronic Pain	32	54.2
3. Psychological Distress (PD)	40	67.8
4. PD + Premorbid Chronic Pain	28	70.0

## Procedures

**BIRC procedures.** Prior to treatment, patients present to BIRC for an initial evaluation. This full-day evaluation consists of a comprehensive psychological interview, cognitive/neuropsychological assessment, a functional capacity evaluation, and a physical examination. Demographic information is also obtained during this process and each patient is assessed using the Mayo-Portland Adaptability Inventory-4 (MPAI-4) on initial evaluation to assess the range of physical, cognitive, emotional, behavioral, and social problems associated with brain injury. This measure is also used as an assessment of major obstacles to community integration that may result from brain injury, as well as problems in the social and physical environment. The MPAI-4 is also administered at discharge, and the Participation subscale is administered both 6 and 12 months post-discharge via mailed survey.

During the psychological interview, biopsychosocial information related to the patient's background and current status is collected, including relevant demographics, pertinent medical history, and involvement in current or pending legal disputes. In addition to the physical

examination, the physiatrist on staff conducts a review of medical records. Information from the medical examination and a review of medical records is then combined with related information reported by the patient and documented in the physiatrist's official medical report. The entirety of collected data and information is recorded and entered into a patient database by BIRC management. Prior to evaluation and treatment, all participants provided authorization to obtain and use protected health information for research purposes.

**Study Procedures:** Demographic information, injury-related information, health-related information, and information regarding functional outcome following mTBI was collected from the patient database at BIRC and entered into Microsoft Excel in preparation for statistical analyses. Specifically, information on pre-injury health status and premorbid chronic pain was obtained from patients' initial medical evaluation report. Demographic, psychosocial, and injury-related information was collected from the comprehensive psychological evaluation report. Demographic and psychosocial information obtained included age, sex, ethnicity/race, marital status, highest level of education obtained, employment status, financial status, involvement in current/pending litigation, and prior mental health diagnoses. Injury-related information obtained included loss of consciousness and the mechanism of injury (e.g., motor vehicle collision, blow to the head, fall from height, physical assault). Patient scores obtained on the (MPAI-4) were also collected from the patient database. No patient names or other identifying information was recorded or collected for the purposes of this study.

## **Measures**

**Mayo-Portland Adaptability Inventory-4 (MPAI-4).** Adaptability was assessed with the MPAI-4, a measure designed to evaluate functional outcome following brain injury during the post-acute period. Items on this measure assess a range of physical, cognitive, behavioral,

emotional, and social problems that are frequently experienced following brain injury. In addition to application in clinical settings, this measure may be effectively employed in research (Malec, 2005). The MPAI-4 consists of three subscales: the Ability Index (i.e., sensory, motor, and cognitive abilities), the Adjustment Index (i.e., mood, interpersonal interactions, and sensitivity to mild symptoms), and the Participation Index (i.e., initiation, social contacts, and societal reintegration). These subscales may be administered at various times during the rehabilitation process in order to assess progress and post-injury limitations. Pre-existing conditions that may affect outcome after brain injury, such as substance use and premorbid health status, are assessed by six additional items that do not contribute to the subscale scores or total score. The MPAI-4 is now considered to be a standardized measure of outcome following brain injury, reflecting functional status as well as psychosocial adjustment and community participation (Sophr-Kusnetz & Benson, 2007).

The MPAI-4 is comprised of 29 items that assess current functioning in each of the three subscale domains. An additional 6 items assess the presence of preexisting conditions that may affect outcome after brain injury, such as substance use and premorbid health status, on a 5-point Likert-type scale. Brief instructions and descriptions on how to complete ratings are provided for each item. The Ability Index and Adjustment Index each consist of 12 items that are rated on a 5-point Likert-type scale ranging from 0 – 4, with 0 indicating no problem, difficulty or interference, and 4 indicating severe problems, difficulty, or interference. The Participation Index is comprised of 8 items that are rated on similar 5-point Likert-type scales ranging from 0 – 4, scaled in terms of the extent of participation in various roles. Raw scores are summed and converted to T-scores, with lower scores indicating less severe consequences of brain injury and fewer limitations.

Design of the MPAI-4 reflects the distinctions between impairment, activity limitations, and participation restriction set forth in the WHO's International Classification of Functioning (ICF; Malec & Lezak, 2008). Established normative data may be used to compare both an individual's Full Scale score and subscale scores with other brain injury survivors. Full Scale T-scores below 30 represent relatively good outcomes, T-scores between 30 and 40 suggest mild limitations, T-scores between 40 and 50 may be considered to reflect mild to moderate limitations, and T-scores between 50 and 60 are considered to fall within the moderate to severely impaired range. T-scores above 60 suggest severe limitations and impairment. Rasch analyses of the MPAI-4 have demonstrated excellent reliability, with person reliability of .88 and item reliability of .99 (Malec & Lezak, 2008). The validity of the MPAI-4 has been established and supported by a variety of statistical techniques in the research, with very acceptable concurrent and predictive validity (Gouvier, Blanton, LaPorte, & Nepomuceno, 1987; Malec, 2001; Malec & Thompson, 1994; Rappaport, Hall, Hopkins, & Bellesa, 1982).

### **Statistical Analyses**

All data utilized for the purposes of this study was de-identified during the data collection process by assigning each case an arbitrary number. De-identified data was then entered into Microsoft Excel in preparation for statistical analyses using SPSS 17.

Data was examined for the presence of outliers through visual inspection of boxplots illustrating MPAI-4 raw score distributions. Further investigation of identified outliers led to the experimenter's conclusion that the scores were not due to data entry errors and that the participants who obtained such scores were appropriate members of the population from which the sample was taken. Therefore, these outliers were retained in the data and included in statistical analyses.

**Hypothesis 1.** The current study was designed to determine whether premorbid chronic pain is associated with lower levels of adaptability, as measured by the MPAI-4, among those who develop postconcussive syndrome following mTBI. For the purposes of this analysis, the presence of premorbid chronic pain was considered the independent variable. Subjects were categorized into either the premorbid chronic pain group (CP+) or absence of premorbid chronic pain group (CP-) based on information contained in their medical records. More specifically, this information was obtained from their initial medical evaluation report, which provides documentation of pre-injury health conditions and chronic pain. In preparation for data analyses this variable was dummy coded, with a score of 1 indicating the presence of premorbid chronic pain (CP+) and a score of 2 indicating that criteria for chronic pain was not present (CP-).

To test the hypothesis that postconcussive patients with premorbid chronic pain will demonstrate lower levels of adaptability following mTBI than those without, independent samples *t*-test analyses were used to assess mean differences between the CP+ and CP- groups on MPAI-4 total scores obtained at initial evaluation. It was assumed that scores on the dependent variable were independent from one another and, thus, the assumption of independence was met. Due to the sample size, ( $n = 59$ ), it was assumed that the dependent variable was normally distributed in each of the two populations; therefore, independent samples *t*-test analyses were deemed appropriate for statistical analyses. Homogeneity of variances was assessed by Levene's Test for Equality of Variances.

**Hypothesis 2.** To test the hypothesis that premorbid chronic pain has a negative effect on subjective post-mTBI impairment and adaptability over time, paired-sample *t*-test analyses were used to assess whether MPAI-4 scores decreased between initial evaluation and treatment discharge in the CP+ and CP- groups, and whether there were significant differences in effect

size between the two groups. It was assumed that difference scores were normally distributed in the population and independent of one another; therefore, paired samples *t*-test analyses were deemed appropriate for statistical analyses.

**Hypothesis 3.** The current study was also designed to determine whether a history of psychological distress is associated with lower levels of adaptability, as measured by the MPAI-4, among those who develop postconcussive syndrome following mTBI. For the purposes of this analysis, a history of psychological distress was considered the independent variable. A history of clinically significant psychological distress was evidenced by prior diagnosis of a mental health disorder, prescribed use of psychotropic medications for psychiatric purposes, or participation in psychological services for treatment of emotional disturbance. This information was obtained from each subject's initial psychological evaluation report and their medical evaluation, both of which provide documentation of mental health history and prior psychological diagnoses. In preparation for data analyses, this variable was dummy coded, with a score of 1 indicating the presence of premorbid psychological distress and a score of 2 indicating that criteria for psychological distress was not present.

To test the hypothesis that postconcussive patients with a history of clinically significant psychological distress will endorse greater overall impairment following mTBI than those who do not, an independent samples *t*-test analysis was used to assess mean differences between the two groups on total MPAI-4 scores at initial evaluation. It was assumed that scores on the dependent variable were independent from one another and, thus, the assumption of independence was met. Due to the sample size, ( $n = 59$ ), it was assumed that the dependent variable was normally distributed in each of the two populations; therefore, independent samples



*t*-test analyses were deemed appropriate for statistical analyses. Homogeneity of variances was assessed by Levene's Test for Equality of Variances.

**Hypothesis 4.** The current study was also designed to determine whether the presence of premorbid chronic health problems is associated with lower levels of adaptability and greater subjective impairment following mTBI in a sample of postconcussive patients, as measured by the MPAI-4. For the purposes of this analysis, the presence of premorbid chronic health conditions was considered the independent variable. Information pertaining to the presence of premorbid chronic health problems was obtained from each subject's initial medical evaluation report, which provides documentation of prior medical diagnoses. Assessment of premorbid chronic health conditions was based on the Center for Disease Control and Prevention's (CDC) diagnostic criteria, which defines chronic diseases as biologically-based, non-communicable conditions of long duration that rarely resolve spontaneously or are completely cured (CDC, 2003). In preparation for data analyses, this variable was dummy coded, with a score of 1 indicating the presence of a premorbid chronic health condition and a score of 2 indicating that criteria for chronic health conditions was not present.

To test the hypothesis that the presence of premorbid chronic health problems will be associated with lower adaptability and greater subjective impairment among postconcussive patients, an independent samples *t*-test analysis was conducted to assess whether mean group differences exist between the two groups on MPAI-4 scores obtained at initial evaluation. It was assumed that scores on the dependent variable were independent from one another and, thus, the assumption of independence was met. Due to the sample size, ( $n = 59$ ), it was assumed that the dependent variable was normally distributed in each of the two populations; therefore,

independent samples *t*-test analyses were deemed appropriate for statistical analyses.

Homogeneity of variances was assessed by Levene's Test for Equality of Variances.

**Hypothesis 5.** Lastly, the current study was designed to determine if involvement in medico-legal proceedings that involve financial incentive, i.e. injury-related litigation and Workers Compensation claims, is associated with lower levels of adaptability and greater subjective impairment following mTBI in a sample of postconcussive patients, as measured by the MPAI-4. For the purposes of this analysis, involvement in medico-legal proceedings was considered the independent variable. Information pertaining to medico-legal status was obtained from each subject's medical chart. In preparation for data analyses this variable was dummy coded, with a score of 1 indicating involvement in medico-legal proceedings and a score of 2 indicating that there was no evidence to suggest the subject was involved in a medico-legal proceeding.

To test the hypothesis that postconcussive syndrome patients involved in current or pending medico-legal proceedings that involve financial incentive will endorse greater subjective impairment following mTBI than those who are not, an independent samples *t*-test analysis was conducted to assess mean differences between the two groups on MPAI-4 scores obtained at initial evaluation. It was assumed that scores on the dependent variable were independent from one another and, thus, the assumption of independence was met. Due to the sample size, ( $n = 59$ ), it was assumed that the dependent variable was normally distributed in each of the two populations; therefore, independent samples *t*-test analyses were deemed appropriate for statistical analyses. Homogeneity of variances was assessed by Levene's Test for Equality of Variances.

The present study did not utilize the Bonferroni approach to address the problem of multiple comparisons across the statistical analyses described above. The decision not to adjust the level of statistical significance ( $p$  value) for the number of analyses performed was based on the rationale that doing so would increase the likelihood of type two errors, such that important differences between groups may be deemed non-significant (Perneger, 1998).

## RESULTS

### Chronic Pain

The current study was designed to determine whether premorbid chronic pain is associated with lower levels of adaptability following mTBI, with subjects being categorized into either the CP+ or CP- groups based on information contained in their medical records. A history of chronic pain was assessed by a review of information contained in subjects' initial medical evaluation report, which provides documentation of pre-injury health conditions and chronic pain information. Of the 59 individuals presenting for treatment of postconcussive sequelae for whom MPAI-4 data was available, 36 (61.0%) met criteria for pre-morbid chronic pain. The CP+ group was largely comprised of females, with 21 (58.3%) endorsing chronic pain as compared to 15 (41.7%) male subjects. For those comprising the CP+ group, falls were the most common mechanism of injury ( $n = 19$ , 52.8%), followed by motor vehicle collisions ( $n = 10$ , 27.8%). Slightly less than half of individuals presenting with premorbid chronic pain were involved in medico-legal proceedings as a result of their injury ( $n = 16$ , 44.4%), as compared to 20 (55.6%) individuals with premorbid chronic pain who were not involved in medico-legal proceedings.

The majority of subjects with premorbid chronic pain ( $n = 32$ , 88.9%) met criteria for a chronic health condition. A history of clinically significant psychological distress was also more common among subjects with premorbid chronic pain, with 28 (77.8%) subjects in the CP+ group meeting criteria, as compared to 12 (52.2%) individuals in the CP- group. Of those with a history of premorbid chronic pain, 25 (69.4%) had received mental health diagnosis in the past, 24 (66.7%) had a history of participating in psychological services, and 20 (55.6%) had been prescribed psychotropic medication prior to their injury.

The presence of post-injury chronic pain was commonly endorsed among subjects who presented for treatment of postconcussive sequelae following mTBI, with 58 (98.3%) individuals reporting persistent pain. The number of body locations affected by post-injury pain varied among subjects, with 39 individuals (66.1%) endorsing pain in multiple areas (see Table 3 for site of post-injury pain information). Of those endorsing persistent pain as a result of their injury, 36 (62.1%) also met criteria for premorbid chronic pain.

Table 3

*Descriptive Statistics for Site of Post-Injury Pain (n =58)*

Location	Total (n)	Percentage in sample (%)
1. Head/headache pain	55	93.2
2. Back pain	26	44.1
3. Neck/jaw pain	32	54.2
4. Upper extremities pain	12	20.3
5. Lower extremities pain	8	13.6
6. Abdominal pain	7	11.9
7. Chest pain	2	3.4
8. Diffuse musculoskeletal/joint pain	2	3.4

### **Premorbid Chronic Pain & Adaptability**

Adaptability to postconcussive sequelae resulting from mTBI was measured using the MPAI-4, with higher scores at initial evaluation representing greater levels of subjective impairment. An independent-samples *t*-test was conducted to evaluate hypothesis 1; that is, to

determine whether postconcussive patients with a history of premorbid chronic pain demonstrate lower levels of adaptability following mTBI than those who do not. This hypothesis was supported. Levene's test for equality of variances was not significant and, thus, equal variances between groups were assumed. The independent-samples  $t$ -test was significant,  $t(57) = 2.41$ ,  $p = .02$ , with postconcussive patients who had a history of chronic pain endorsing lower levels of adaptability following mTBI ( $M = 57.58$ ,  $SD = 8.23$ ) than those who did not ( $M = 51.78$ ,  $SD = 10.09$ ). The 95% confidence interval for the difference in means ranged from .98 to 10.62. The 95% confidence intervals for mean MPAI-4 scores of the CP+ and CP- groups at initial evaluation are presented in Figure 1. The obtained eta square value indicated a medium effect size, with approximately 9.1% of the variance in MPAI-4 scores received at initial evaluation being accounted for by a history of premorbid chronic pain.

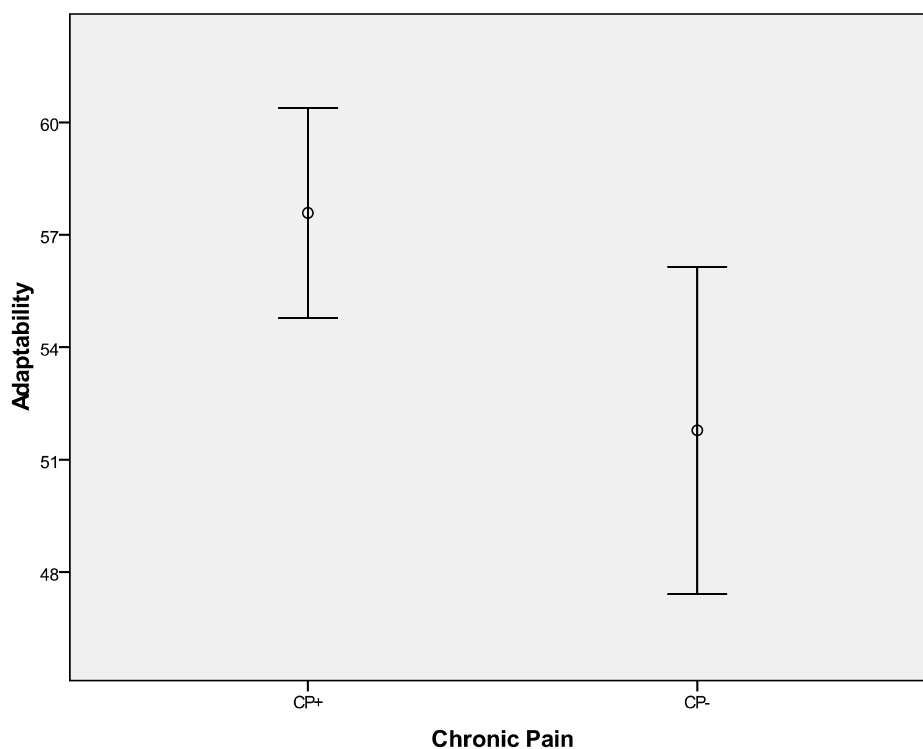


Figure 1. 95% confidence intervals for MPAI-4 scores

### **Premorbid Chronic Pain & Adaptability Over Time**

Of the 59 subjects whose medical charts were reviewed for the purposes of this study, 29 provided MP AI-4 scores at both initial assessment and discharge. This subset of participants was comprised of slightly more males ( $n = 15$ , 51.7%) who self-identified as Caucasian ( $n = 22$ , 75.9%). Falls were the most common mechanism of injury ( $n = 14$ , 48.3%), followed by blows to the head ( $n = 7$ , 24.1%) and motor vehicle collisions ( $n = 6$ , 20.7%). The majority of these subjects ( $n = 17$ , 58.6%) sustained an mTBI while at work and 15 (51.7%) were involved in medico-legal proceedings as a result of their injury. Of the 29 data sets that were analyzed for the purposes of this study, 22 (79.3%) documented the presence of premorbid chronic pain. The majority of these subjects also met criteria for a history of psychological distress ( $n = 24$ , 82.8%) and a chronic health condition ( $n = 21$ , 72.4%).

To test the hypothesis that premorbid chronic pain has a negative effect on adaptability and resumption of societal roles following mTBI over time paired  $t$ -test analyses were conducted. Specifically, paired-sample  $t$ -tests were conducted to evaluate hypothesis 2, that is to determine whether postconcussive patients with a history of premorbid chronic pain demonstrate less subjective improvement and adaptability over time than those without a history of premorbid chronic pain, as measured by the MP AI-4. The results indicated that the mean difference in MP AI-4 scores between initial evaluation and discharge for the CP+ group ( $M = 5.57$ ,  $SD = 4.54$ ) was significant,  $t(22) = 5.88$ ,  $p = .00$ . The 95% confidence interval for the difference in means ranged from 3.60 to 7.53. The results of this analysis indicated a significant time effect, with an obtained eta square value of .44.

A second paired-samples  $t$ -test conducted to evaluate the mean difference in MP AI-4 scores assessed during initial evaluation and discharge for the CP- group ( $M = 4.83$ ,  $SD = 4.45$ )

was also significant,  $t(5) = 2.66, p = .05$ . The 95% confidence interval for the difference in means ranged from .17 to 9.50. The results of this analysis also indicated a significant time effect, with an obtained eta square value of .42. However, it is important to note that only six pairs of MPAI-4 scores taken at initial evaluation and discharge were available for analysis of the CP- group, with such a small sample size highly compromising the validity and generalizability of these statistical results.

In order to determine whether those with a history of premorbid chronic pain demonstrated significantly less improvement over time than those without a history of premorbid chronic pain, an independent-samples  $t$ -test analysis was conducted to assess the mean difference between the effect sizes of the CP+ and CP- groups. Levene's test for equality of variances was not significant and, thus, equal variances between groups were assumed. The independent-samples  $t$ -test was not significant,  $t(27) = .35, p = .73$ , with the 23 postconcussive patients who had a history of premorbid chronic pain ( $M = 5.57, SD = 4.54$ ) demonstrating a similar degree of subjective improvement over time as the 6 subjects who did not have a history of premorbid chronic pain ( $M = 4.83, SD = 4.45$ ). The 95% confidence interval for the difference in means ranged from -3.52 to 4.99

### **Psychological Distress & Adaptability Following mTBI**

The majority of subjects presenting to BIRC for evaluation and treatment of residual postconcussive impairment following mTBI had a pre-injury history of clinically significant psychological distress ( $n = 40, 67.8\%$ ), as evidenced by prior diagnosis of a mental health disorder ( $n = 35, 59.3\%$ ), participation in psychological services prior to their injury ( $n = 30, 50.9\%$ ), or prescribed use of psychotropic medication for psychiatric purposes

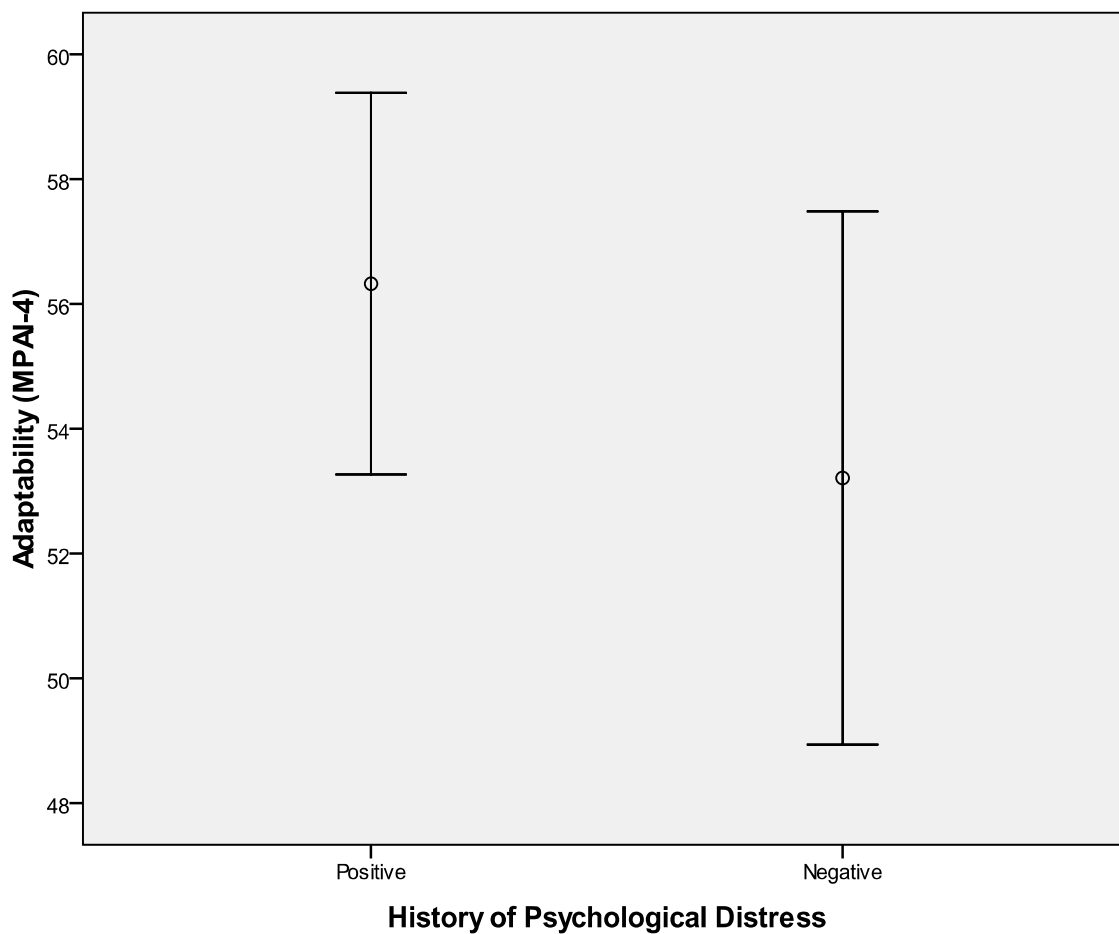


( $n = 24$ , 40.7%). Of individuals with a history of mental health treatment, 4 (6.8%) required psychiatric hospitalization.

The majority of those who had been previously diagnosed with a psychological condition carried one mental health diagnosis ( $n = 15$ , 25.4%). The most common mental health conditions were depressive disorders, with 23 (38.9%) participants in the sample carrying a related diagnosis. A history of clinically significant anxiety was also common, with 21 (35.6%) subjects having been formerly diagnosed with a related disorder. A history of trauma, i.e. childhood, sexual, physical abuse, was present in 9 (15.3%) cases, with 2 of these subjects being described as having borderline personality features. Rates of attention deficit/hyperactivity disorders ( $n = 7$ , 11.9%) and substance-related disorders ( $n = 6$ , 10.2%) in the sample were also elevated.

To evaluate hypothesis 3, that is that postconcussive syndrome patients with a history of clinically significant psychological distress will endorse greater overall impairment following mTBI than those who do not, an independent samples  $t$ -test analysis was used to assess the mean difference between the two groups on MPAI-4 scores at initial evaluation. This hypothesis was not supported. Levene's test for equality of variances was not significant and, thus, equal variances between groups were assumed. The independent-samples  $t$ -test was not significant,  $t(57) = 1.20$ ,  $p = .24$ , with postconcussive patients who had a history of clinically significant psychological distress endorsing a similar degree of impairment following mTBI ( $M = 56.33$ ,  $SD = 9.57$ ) than those who did not ( $M = 53.21$ ,  $SD = 8.87$ ). The 95% confidence interval for the difference in means ranged from -2.10 to 8.33. The 95% confidence intervals for mean MPAI-4 scores of the two groups at initial evaluation are presented in Figure 2. The obtained eta square value indicated a small effect size, with approximately 2.4% of the variance

in MPAI-4 scores received at initial evaluation being accounted for by a history of clinically significant psychological distress.



*Figure 2.* 95% confidence intervals for MPAI-4 scores

In order to better clarify the difference between those with a history of clinically significant psychological distress and those without, a second independent-samples *t*-test was conducted to assess the mean difference between the two groups on MPAI-4 scores at initial assessment after those who also endorsed a history of premorbid chronic pain were removed from analyses. Levene's test for equality of variances was not significant and, thus, equal variances between groups were assumed. The independent-samples *t*-test was not significant, *t*

(21) = .98,  $p = .34$ , with 12 postconcussive patients who had a history of clinically significant psychological distress and no premorbid chronic pain endorsing a similar degree of impairment following mTBI ( $M = 53.75$ ,  $SD = 10.94$ ) as the 11 individuals who had neither a history of psychological distress or premorbid chronic pain ( $M = 49.64$ ,  $SD = 9.11$ ). The 95% confidence interval for the difference in means ranged from -4.66 to 12.89.

### **Chronic Health Conditions & Adaptability Following mTBI**

The current study was also designed to determine whether the presence of premorbid chronic health problems, as evidenced by prior medical diagnoses, was associated with lowered adaptability and greater subjective impairment following mTBI in a sample of postconcussive patients, as measured by MPAI-4 scores at initial evaluation. Assessment of premorbid chronic health conditions was based on the Center for Disease Control and Prevention's (CDC) diagnostic criteria, which defines chronic diseases as biologically-based, non-communicable conditions of long duration that rarely resolve spontaneously or are completely cured (CDC, 2003).

Of the 59 participants presenting for treatment of postconcussive sequelae whose charts were reviewed for the purposes of this study, 33 (55.9%) individuals were identified as having a premorbid chronic health condition (see Table 4 for a list of included chronic health conditions). Hypertension and hyperlipidemia were not considered chronic health conditions for the purposes of this study, as neither typically have a high degree of illness intrusiveness. The majority of subjects comprising the CHC group were identified as having more than one chronic health condition prior to their injury ( $n = 27$ , 81.8%). The chronic health condition group (CHC) was largely comprised of females ( $n = 21$ , 63.6%), as compared to males ( $n = 12$ , 36.4%). The vast

majority of subjects comprising the CHC group also endorsed a history of premorbid chronic pain ( $n = 32$ , 97.0%), as well as a history of psychological distress ( $n = 27$ , 81.8%).

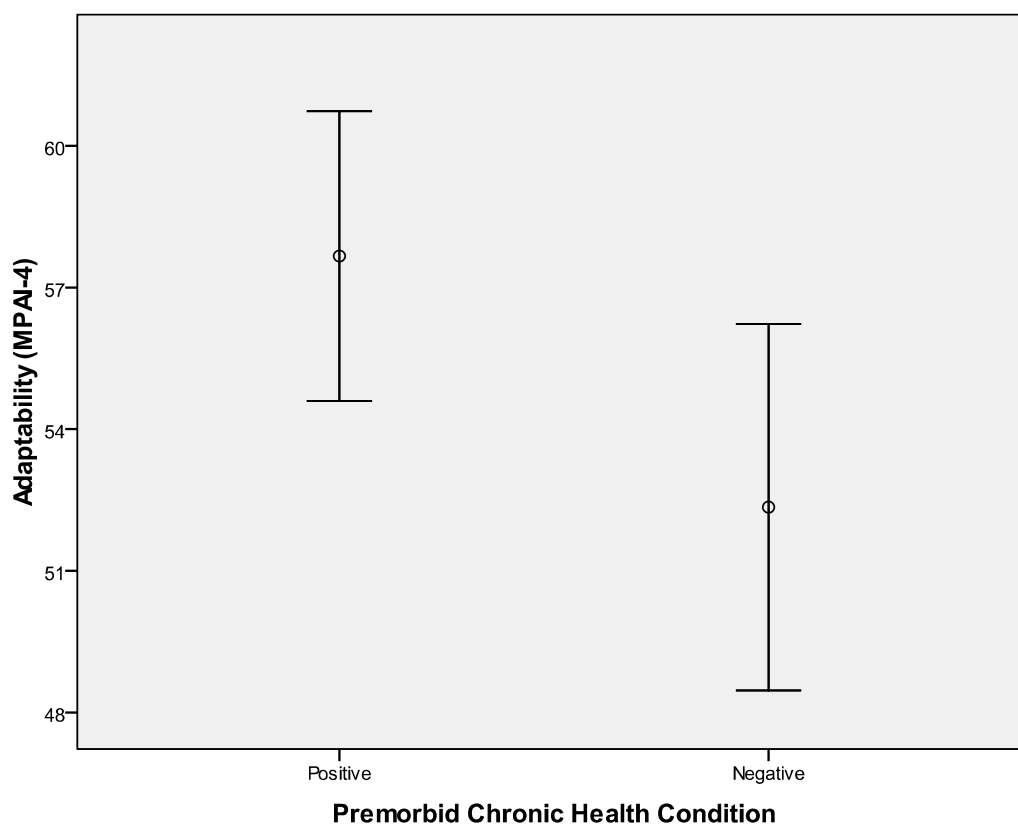
Table 4

*Descriptive Statistics for Pre-Injury Health Conditions (n =33)*

Location	Total (n)	Percentage in sample (%)
1. Idiopathic chronic pain condition	15	68.2
2. Migraines	11	50.0
3. Degenerative disc disease	10	45.5
4. Diabetes mellitus	10	45.5
5. Esophageal reflux disease/GERD	8	36.4
6. Obesity	7	31.8
7. Arthritis (osteo/rheumatoid)	6	27.3
8. Thyroid dysfunction	5	22.7
9. Asthma/reactive airway disease	4	18.2
10. Sleep/fatigue/arousal disorder	4	18.2
11. Heart/vascular disease	3	13.6
12. Ulcerative colitis	2	9.1
13. Polycystic ovarian syndrome	2	9.1
14. Labyrinthitis	1	4.6
15. Hepatitis C	1	4.6
16. Systemic lupus erythematosus	1	4.6

Falls were the most common mechanism of injury ( $n = 19$ , 57.6%) for the CHC group, followed by motor vehicle collisions ( $n = 8$ , 24.2%). Slightly over half of those in this group sustained a work-related mTBI ( $n = 18$ , 54.5%), with 16 (48.5%) related medical charts documenting current or planned involvement in medico-legal proceedings that involve a financial incentive.

An independent-samples  $t$ -test was conducted to evaluate hypothesis 4; that is, to determine whether postconcussive patients with premorbid chronic health problems, as evidenced by prior medical diagnoses, demonstrate lowered adaptability and greater subjective impairment following mTBI than those who do not. This hypothesis was supported. Levene's test for equality of variances was not significant and, thus, equal variances between groups were assumed. The independent-samples  $t$ -test was significant,  $t(57) = 2.24$ ,  $p = .02$ , with postconcussive patients who had a premorbid chronic health condition endorsing greater subjective impairment following mTBI ( $M = 57.67$ ,  $SD = 8.65$ ) than those who did not ( $M = 52.35$ ,  $SD = 9.61$ ). The 95% confidence interval for the difference in means ranged from .55 to 10.09. The 95% confidence intervals for mean MPAI-4 scores of the two groups at initial evaluation are presented in Figure 3. The obtained eta square value indicated a medium effect size, with approximately 8.1% of the variance in MPAI-4 scores received at initial evaluation being accounted for by the presence of a premorbid chronic health condition.



*Figure 3. 95% confidence intervals for MPAI-4 scores*

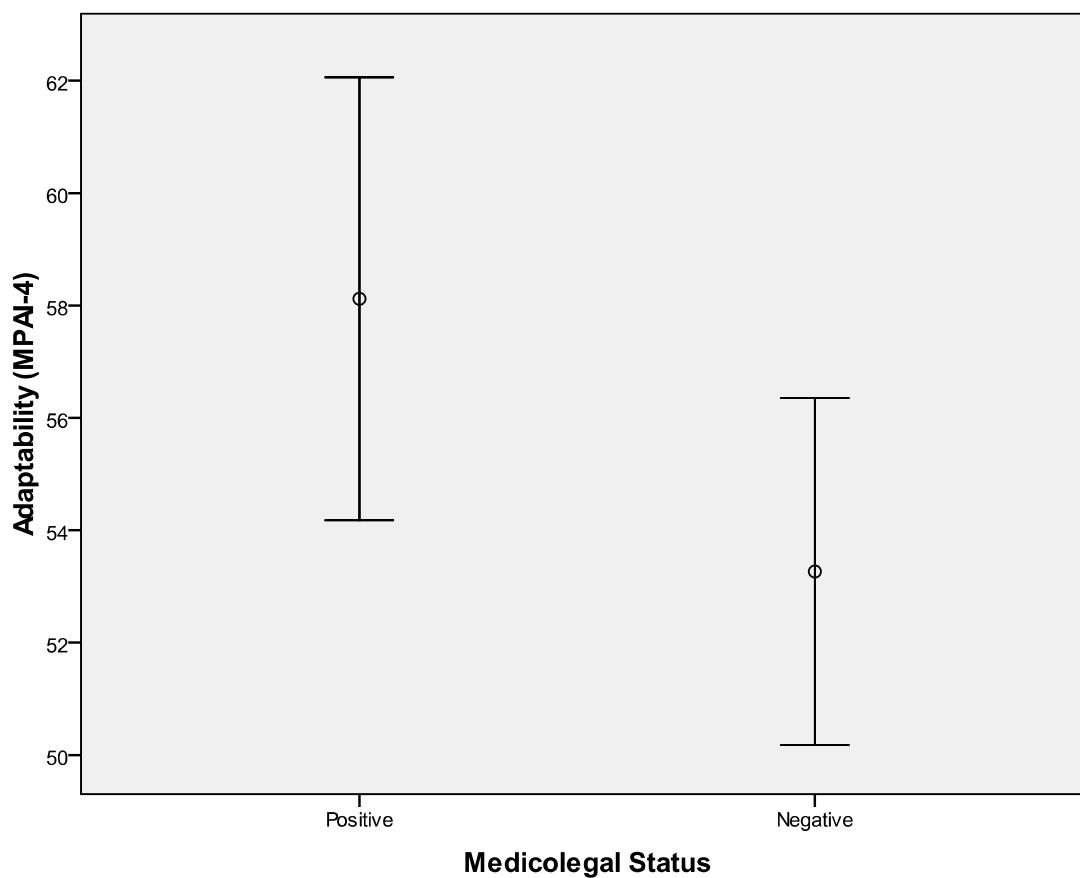
In order to better clarify the difference between those with and without a premorbid chronic health condition, a second independent-samples *t*-test was attempted to assess the mean difference between the two groups on MPAI-4 scores at initial evaluation after those who also endorsed a history of premorbid chronic pain were removed from analyses. This attempt was unsuccessful, as 32 of the 33 subjects who met criteria for a chronic health condition, carried at least one premorbid medical diagnosis commonly associated with persistent pain. This overlap between those with premorbid chronic pain in addition to a history of chronic health conditions represents a significant confound and is, thus, a major limitation of this archival research study.

### **Medico-legal Proceedings & Subjective Impairment Following mTBI**

This study was also designed to determine whether postconcussive patients involved in current or pending medico-legal proceedings that involve financial incentive, i.e. injury-related litigation and Workers Compensation claims, endorsed greater subjective impairment following mTBI than those who are not. Of the 59 medical charts reviewed for the purposes of this study, 25 (42.4%) contained documentation indicating that the associated subject was either currently involved in, or planning to initiate, medico-legal proceedings related to their injury, or were receiving time-loss/Workers Compensation wages. Of these 25 subjects, 16 (64.0%) also met criteria for premorbid chronic pain and 16 (64.0%) had a documented chronic health condition. In addition to the presence of premorbid chronic pain, the majority of individuals pursuing medico-legal action as a result of their injury had a history of psychological distress ( $n = 19, 76.0\%$ ).

An independent-samples  $t$ -test was conducted to evaluate hypothesis 5, that is to determine whether postconcussive patients involved in current or pending medico-legal proceedings that involve financial incentive, i.e. injury-related litigation and Workers Compensation claims, endorsed greater overall impairment on the MPAI-4 at initial evaluation than those who are not involved in such proceedings. This hypothesis was supported. Levene's test for equality of variances was not significant and, thus, equal variances between groups were assumed. The independent-samples  $t$ -test was significant,  $t(57) = 2.01, p = .05$ , with postconcussive patients involved in medico-legal proceedings endorsing greater subjective impairment following mTBI ( $M = 58.12, SD = 9.55$ ) than those who did not ( $M = 53.26, SD = 8.85$ ). The 95% confidence interval for the difference in means ranged from .03 to 9.68. The 95% confidence intervals for mean MPAI-4 scores of the two groups at initial

evaluation are presented in Figure 4. The obtained eta square value indicated a medium effect size, with approximately 6.6% of the variance in MPAI-4 scores received at initial evaluation being accounted for by involvement in medico-legal proceedings.



*Figure 4.* 95% confidence intervals for MPAI-4 scores



## DISCUSSION

### **Premorbid Chronic Pain & Adaptability Following mTBI**

The present study was designed to examine the relationship between premorbid chronic pain and postconcussive syndrome in an effort to enhance our understanding of factors that serve to mediate the functional expression of impairment, disability, and variability in adaptation following mTBI. Using an archival research design, our sample included patients who presented for evaluation and treatment of postconcussive sequelae at a day-treatment rehabilitation setting in Portland, Oregon following mTBI.

Overall, the results of this study support the hypothesis that postconcussive patients with a history of premorbid chronic pain differ from those who do not have a history of premorbid chronic pain in terms of adaptability following mTBI. More specifically, findings from the present study suggest that postconcussive patients who have a history of premorbid chronic pain demonstrate greater subjective impairment and lower levels of adaptability following mTBI than those who do not. This supports the hypothesis that premorbid coping vulnerabilities associated with chronic pain symptomology play a predominant role in mediating the impact of functional impairments associated with PCS.

Results from the present study did not support the hypothesis that postconcussive patients with a history of premorbid chronic pain differ in terms of their subjective post-mTBI impairment, adjustment, and resumption of societal roles over time as compared to those who do not have a pre-injury history of chronic pain. More specifically, findings from the current study suggest that postconcussive patients who have a history of premorbid chronic pain demonstrate a similar degree of subjective improvement over time than those who do not have preexisting pain. However, it is important to note that only six pairs of MPAI-4 scores taken at initial evaluation

and discharge were available for analysis of the CP- group, with such a small sample size highly compromising the validity and generalizability of these statistical results. This negative finding may also be reflective of the quality of rehabilitation services provided by a fee-for-service treatment center located in the Pacific Northwest. Longitudinal research studies that involve larger sample sizes may help clarify differences in functional outcome between these two groups over time.

The finding that premorbid chronic pain is associated with lower levels of adaptability among postconcussive patients is consistent with previous research that suggests pre-jury variables and biopsychosocial factors have direct implications for the development and maintenance of postconcussive sequelae (McLean et al., 2008; McNally et al., 2013; Whittaker & Kemp, 2007). Common demographics of our postconcussive patient sample included Caucasian ethnicity (83.1%), female sex (59.3%), and lower education (40.7%), all of which are consistent with demographic predictors of persistent post-mTBI impairment as described by previous studies (Dischinger, Ryb, Kufera, & Auman, 2009; Meares et al., 2008; Ponsford et al., 2000; Stulemeiger, Vos, Bleijenberg, & van der Werf, 2007).

The presence of post-injury pain was commonly endorsed by individuals comprising our sample, with 58 (98.3%) subjects reporting persistent pain. This is consistent with research that suggests concomitant pain syndromes are more frequently endorsed by individuals who have sustained milder TBIs as compared to those who suffered more severe insults to the brain (Martelli, Bender, Nicholson, & Zasler, 2002; Nampiaparampil, 2008; Uomoto & Esselman, 1993). The presence of post-injury pain may serve to further exacerbate mTBI residua, as pain is known to be associated with a variety of cognitive deficits characteristic of PCS (Beupre, DeGuise, & McKerral, 2012; Smith-Seemiller, Fow, Kant, & Franzen, 2003).

The most common type of post-injury pain reported by individuals comprising our sample was headache, which was endorsed by 55 (93.2%) subjects. The finding that posttraumatic headache is a common physical manifestation of milder injuries to the brain is consistent with the work of Rimel et al. (1981), who reported the prevalence of persistent headaches to be 79% in their sample of postconcussive patients, as well as a study by Uomoto and Esselman (1993), which found that 89% of mTBI patients endorsed post-injury headaches as compared to 18% of patients with moderate-severe brain injuries. The finding of previous research that preexisting headache syndromes are often exacerbated by mTBI may be particularly relevant to the present study, as 14 (23.7%) of our sample had a documented pre-injury history of recurrent migraines (Jensen & Nielsen, 1990; Landy, 1998).

The notion that premorbid chronic pain is associated with greater subjective impairment and lower levels of adaptability is consistent with research that has found that somatically-focused individuals preoccupied with physical symptoms are vulnerable to poor outcome following mTBI, as they are more likely to demonstrate sensitivity to bodily sensations and have a heightened perception of health vulnerability (Ruff, Mueller, & Jurica, 1996). This is also consistent with experimental evidence reported by McBeth, Macfarlane, Bengamin, and Silman (2001), who found that individuals with a history of somatic symptoms were most vulnerable to symptom exacerbation after stress or injury. Providing further support is the work of Ruff (2005) and Wood (2004), both of whom found that prolonged stress that occurs during recovery from injury contributes to the development and maintenance of postconcussive sequelae. It has been suggested that perceived stress is associated with persistent psychological and physical symptoms following mTBI, as residual cognitive symptoms may be ascribed meaning through

interpretation of the context in which they occur and perceptions of one's ability to cope (Bay & Sikorskii, 2009).

An ample body of research has supported the assertion that chronic pain represents a significant stressor that has been shown to drastically affect self-efficacy beliefs and perceived coping abilities, which in turn are associated with poor health outcome (Arnstein, Caudill, Mandel, Norris, & Beasley, 1999; Asghari & Nicholas, 2006). Consistent with this assertion are results from the present study, which indicate that a history of psychological distress (77.8%) and chronic health conditions (88.9%) were endorsed by the majority of postconcussive patients presenting with a history of chronic pain, who, as a group, collectively endorsed greater subjective impairment and lower levels of adaptability than those without persistent premorbid pain.

Supporting the connection between premorbid chronic pain and poor adaptation following mTBI is Satz's (1993) theory of cognitive reserve, which conceptualizes outcome according to a demand versus resources model that weights premorbid psychosocial and coping resources against new demands associated with brain injury. It has long been emphasized that once developed, chronic pain can cause profound disruptions to various domains of life, including emotional, physical, economic, and social problems (Turks et al., 2008). The broad negative impact of chronic pain on health-related quality of life has been documented to exacerbate daily stressors, lower self-efficacy, and increase vulnerability to the effects of perceived shortcomings (Asghari & Nicholas, 2001). Chronic pain has also been demonstrated to reduce access to protective factors that serve to buffer the deleterious effects of increased stress (Turks et al., 2008). After brain injury, it seems reasonable to assume that an individual's

premorbid capacity for coping and related skills would serve to mediate adaptation to novel symptoms or limitations.

Research investigating the role of premorbid biopsychosocial factors on outcome following brain injury has been lacking, largely due to the difficulty of obtaining reliable information from patients and problems associated with disentangling factors that contribute to impairment, disability, and post-injury residua (Dikman, 1995). Studies that have been conducted tend to focus on trauma-related variables and other biomedical factors, rather than examining pre-injury biopsychosocial status. This is especially problematic given the finding that non-injury factors are more consistently related to persistent postconcussive sequelae than injury characteristics (McNally et al., 2013). A lack of research investigating the impact of pre-injury variables on outcome following mTBI has limited our understanding of factors that contribute to the myriad of symptoms characteristic of PCS, many of which are not amenable to objective medical testing.

Given the rising prevalence of chronic pain and mTBI, deficient understanding of the contributory mechanisms involved in the development and maintenance of these conditions is particularly problematic. Epidemiological research has estimated community prevalence rates of chronic pain to be as high as 50%, rates that are expected to continue rising in the foreseeable future (Becker et al., 1997; Elliot et al., 1999; Hardt et al., 2008). Findings from the present study are consistent with such estimations, as 61% of subjects whose medical charts were reviewed for the purposes of this study had a documented history of chronic pain prior to the injury. Also consistent with a large body of previously reported literature, the prevalence of chronic pain was found to be higher among women than men in our sample (Bouhassira et al., 2008; Hardt et al., 2008; Tunks et al., 2008). Though multiple hypotheses have been proposed to explain this

gender disparity, reasons underlying these differences remain unclear. It seems likely that a variety of interacting situational, biological, and socio-cultural factors are involved.

Given the increasing incidence of chronic stress-related disorders as well as mTBI, which now represents the most common neurological condition in North America, it is not unreasonable to assume the rates of postconcussive syndrome will also continue to rise in the years ahead (Vazaruab, McClung, Shah, et al., 2005). This is supported by the finding that subtle structural deficits associated with mTBI can affect neural systems involved in regulation of the brain's stress circuitry (Bay, Kalpakjian, & Giordani, 2012; Herman et al., 2003; Stulemeijer et al., 2010). Diminished functionality of stress regulation systems may in turn serve to exacerbate chronic pain and health conditions following mTBI. The magnitude of these findings highlight the necessity of further investigation in the service of obtaining a level of detailed understanding necessary for the development of efficient strategies for the management of such conditions.

Considering the increasingly high prevalence rates of mTBI, it is neither realistic nor necessary to engage all individuals with these injuries in comprehensive treatment. However if replicated by future studies, the finding that premorbid chronic pain is associated with PCS could promote assessment of pre-injury factors that could be used to identify individuals with high vulnerability for poor outcome and to inform/guide treatment. Such screening could serve to decrease the morbidity that chronic pain additionally imposes on those who sustain mTBI. This assertion is supported by the research of Mittenberg, Canyock, Condit, and Patton (2001), who found that single-session interventions can be effective in preventing the development of persistent postconcussive symptoms following mTBI in at-risk individuals. Increased recognition of the effects of premorbid chronic pain on post-mTBI symptoms could allow for the early

provision of interventions that circumvent ongoing problems, which would minimize the potential for chronic disability and unnecessary healthcare costs.

### **Premorbid Psychological Distress & Adaptability Following mTBI**

An additional objective of the present study was to determine whether either a history of psychological distress was associated with lower levels of adaptability among postconcussive patients presenting for treatment after sustaining an mTBI.

Of those PCS patients whose charts were reviewed for the purposes of this study, 40 (67.8%) were deemed to have a history of clinically significant psychological distress, as evidenced by prior diagnosis of a mental health disorder, participation in psychological services prior to their injury, or prescribed use of psychotropic medications for the treatment of a psychological disorder. This finding is consistent with the work of Klonoff and Lamb (1998), who found that pre-injury psychiatric disorders were more common among those who developed postconcussive sequelae following mTBI than those who did not.

The most common pre-existing mental health disorders associated with our sample were depressive disorders, with 23 (38.9%) participants in the sample carrying a related diagnosis. This finding is not surprising given the reported rates of comorbidity between chronic pain and depression (MacMillan, Hart, Martelli, & Zasler, 2002; Martelli, Zasler, Bender, & Nicholson, 2004; Smith-Seemiller, Fow, Kant, & Franzen, 2003). This finding is also consistent with the results of a study by Mathias and Coats (1999), who found that individuals who experienced persistent postconcussive sequelae were more likely to report a history of depressive symptomology prior to their injury.

In terms of pre-injury psychological distress and adaptability following mTBI, the results of this study did not support the hypothesis that postconcussive patients who have been

diagnosed with a mental health disorder, prescribed psychotropic medications for psychiatric purposes, and/or participated in psychological services for treatment of emotional disturbance differ from those without a documented history of clinically significant psychological distress. More specifically, findings from this study suggest that postconcussive patients who have a documented history of psychological distress do not endorse greater overall impairment and lower levels of adaptability following mTBI than those who do not.

This finding is inconsistent with a large body of research that has found pre-injury psychiatric disturbance to be associated with negative outcome and persistent cognitive residua following brain injury (Carroll et al., 2004; Kashluba, Paniak, & Casey, 2008; MacMillian et al., 2002; McLean et al., 2009; Rutherford, 1989; Ruff, 2005; Wood, 2004). After summarizing case study data on the topic, Martelli (1998) concluded that a history of psychological adversity represents a significant obstacle to optimal adaptation following brain injury, as concurrent psychiatric symptoms may contribute to or amplify postconcussive sequelae.

Ponsford et al. (2012), suggest that individuals with premorbid psychiatric disturbance may react to mTBI and postconcussive sequelae with increased anxiety and catastrophic interpretation, which serves to further exacerbate cognitive impairment. Consistent with this assertion is the work of Rapoport, Kiss, and Feinstein (2006), who found that individuals with pre-existing mood disorders endorsed greater degrees of psychosocial dysfunction and PCS-related interference following mTBI, and a study by Trahan and colleagues (2001), which found substantially higher endorsement of postconcussive symptoms among mTBI patients with a history of clinically significant psychological distress. The relationship between mood disturbance and PCS has similarly been reported by Fann and colleagues (1995), who suggest



that concomitant depression is associated with persistent disability and poor psychosocial outcome following mTBI.

However surprising, the present study's finding that a documented history of psychological distress was not associated with lower levels of adaptability and poor outcome following mTBI is similar to the work of Hou and colleagues (2012), who suggest that cognitive factors and behavioral coping responses are more important predictors of persistent post-mTBI residua than emotional variables, such as premorbid psychopathology. When cognitive and behavioral factors were added to their proposed model of PCS, these authors found that emotional variables were no longer able to predict persistent postconcussive sequelae among a sample of mTBI patients.

Several confounding factors may have contributed to this non-significant finding. Medical charts may not have contained accurate information regarding premorbid psychiatric status, as it is not uncommon for psychological conditions to be overlooked or minimized in medical settings (Al-Huthail, 2008; Dilts, Mann, & Dilts, 2003; Yamada, 2008). As such, it is not uncommon for mental health disorders to go undiagnosed and untreated. This assertion is further supported by the work of Oliver, Pearson, Coe, and Gunnell (2005), who approximate that only a quarter of individuals in the community with significant psychological distress seek professional treatment from a health professional. This may be especially true in the case of Axis II disorders, as Hibbard and colleagues (2000) found that it is not uncommon for pre-existing personality disorders to go undiagnosed until post-injury adjustment problems necessitate further assessment and treatment. It is also possible that the demographic composition of our sample contributed to the non-significance of this finding. Given the large percentage of individuals involved in medico-legal proceedings, it is possible that the presence of pre-existing psychiatric

symptoms were minimized by patients, for fear that longstanding mental health problems may be used to invalidate their injury-related claims.

Another potential factor that may have contributed to this non-significant finding is the criteria utilized by the present study to determine a history of clinically significant psychological distress. According to this set of criteria, individuals who had accessed mental health services in the past were deemed to have a history of psychological disturbance. This may have skewed our findings, as psychologically healthy individuals who happened to have accessed these services in the past for more benign or non-clinical reasons, may have been inaccurately classified as having a history of psychiatric disturbance.

### **History of Chronic Health Conditions & Adaptability following mTBI**

Another objective of the present study was to determine whether the presence of chronic premorbid health conditions that typically involve a high degree of illness intrusiveness was associated with lower levels of adaptability among postconcussive patients presenting for treatment following mTBI. In terms of premorbid medical conditions, the results of the current study support the hypothesis that postconcussive patients with a history of chronic health conditions differ from those without. More specifically, findings from the present study suggest that postconcussive patients with premorbid health conditions of a chronic nature, as evidenced by prior medical diagnoses, demonstrate greater subjective impairment and lower levels of adaptability following mTBI than those who do not have a history of chronic health conditions.

This finding should be interpreted with caution, as 32 of the 33 subjects who met criteria for a chronic health condition carried at least one premorbid medical diagnosis commonly associated with persistent pain. As a result of this considerable overlap, attempts to clarify the difference between those with and without a premorbid chronic health condition by removing

those who also had a history of chronic pain were unsuccessful and it is unclear which factor was responsible for the difference between groups. The overlap between those with premorbid chronic pain in addition to a history of chronic health conditions represents a significant confound that is a major limitation of this archival research study. For this reason, it is imperative that further research be conducted to confirm this result. Studies that involve larger sample sizes and utilize multiple regression analyses in order to estimate the relationships between premorbid chronic health conditions, pain quality, and illness intrusiveness may help to further clarify differences in functional outcome following mTBI.

If this finding were to be confirmed, it would be consistent with the work of Martelli, Zasler, and MacMillan (1998), who found that consideration of a patient's premorbid medical history could be used to accurately predict outcome following milder brain injuries. Similarly, results from a study by Stulemeijer and colleagues (2008) suggest that a history of poor physical functioning is significantly associated with persistent cognitive complaints 6 months following mTBI. Such results would also be consistent with experimental evidence reported by McBeth, Macfarlane, Bengamin, and Silman (2001), who found that individuals with a history of somatic symptoms were more vulnerable to symptom exacerbation after stress or injury, and the work of Hou and colleagues (2012), who found that individuals with a history of somatic complaints were more vulnerable to developing postconcussive sequelae following mTBI than those without.

The authors' finding that a history of chronic health conditions that involve a high degree of illness intrusiveness are associated with poor outcome following mTBI is consistent with allostatic load theory, which posits that regulation of neurologically-based stress systems is necessary for healthy adaptation to psychosocial threat and that chronic stress may contribute to

changes in perceived cognitive abilities (Bay, Kalpakjian, & Giordani, 2012; McEwen, 2003). Related research has documented the deleterious effects of dysregulated stress systems, as seen in mTBI and chronic health conditions, which include structural damage to the brain, psychopathology, exacerbation of pre-existing somatic symptoms, and poor health outcome (Bay, Kirsch, & Gillespie, 2004; Herbert et al., 2006).

A study by Lannsjo and colleagues (2009) found that somatic symptoms associated with PCS, such as fatigue, headaches, and sleep disturbance, are the most common type of sequelae endorsed by those presenting for treatment of post-mTBI residua. Such symptoms may be more pronounced in individuals with pre-existing chronic conditions, as they already have compromised health and are more likely to maintain a heightened sense of health vulnerability. According to Ruff, Mueller, and Jurica (1996), somatically focused individuals who maintain preoccupations with their health are more likely to endorse a number of pre-existing physical symptoms intermixed with novel or changing post-injury sequelae following mTBI. Supporting this assertion is the finding that poor physical health status at baseline was the strongest predictor of postconcussive symptoms following minor trauma (McLean et al., 2008). Findings from the present study are also consistent with the work of McNally and colleagues (2012), who found that premorbid somatic symptoms were the strongest predictor of postconcussive sequelae over time following mTBI. These authors go on to stress the importance of assessing pre-injury health factors that may lead to longer or more complicated recoveries in this patient population.

It may be that individuals with a history of chronic health conditions are more likely to maintain negative illness perceptions that increase their likelihood of developing persistent symptoms following mTBI. For instance, they may be more likely to have low illness control and to believe residual symptoms will last a long time and/or negatively impact their functioning,

factors that have all been found to predict PCS (Hou et al., 2012; Whittaker & Kemp, 2007). This is consistent with prior research that has documented that individuals with stronger beliefs about the seriousness of novel symptoms and the related impact on their ability to cope are at increased risk for developing persistent postconcussive sequelae (Snell, Hay-Smith, Surgenor, & Siegert, 2013; Whittaker, Kemp, & House, 2007). This assertion is further supported by research on psychosocial factors involved in the development and maintenance of PCS, which suggests that negative illness perceptions and expectations are potential risk factors (Whittaker & Kemp, 2007). Negative interpretations of somatic sensations and maladaptive coping tendencies have been found to predict chronic symptoms post-mTBI (Hou et al., 2012).

A heightened level of somatic awareness associated with a history of chronic illness or pain may serve to sensitize an individual to cognitive sequelae resulting from mTBI. Hyper-focused attention on post-injury symptoms may lead to catastrophizing, increased stress, and psychopathology, which can result in further exacerbation of both pre-existing health conditions and post-mTBI sequelae. Supporting this assertion is a study by Greiffenstein and Baker (2001), which found that the pre-injury MMPI-2 profiles of postconcussive patients were elevated and predominantly characterized by somatoform symptoms and pervasive health concerns, as well as the work of Snell and colleagues (2013), who found that individuals who maintained greater degrees of health-related distress and stronger beliefs regarding patient identity at the time of their injury were at greater odds for poor outcome.

Similar to those with a pre-injury psychiatric history, individuals with premorbid chronic health problems may react to postconcussive sequelae with greater anxiety, which then serves to exacerbate and perpetuate cognitive symptoms. Further, environmental variables that serve to reinforce illness behaviors, such as over solicitous attention and support from family members or

loved ones, have been found to interact with certain personality traits and problematic coping tendencies to produce differential adaptation within brain injured and chronic pain populations (Martelli, Zasler, & MacMillan, 1998).

### **Medico-Legal Proceedings & Adaptability Following mTBI**

The present study was also designed to examine the relationship between postconcussive sequelae and involvement in medico-legal proceedings that involve financial incentive, e.g. injury-related litigation and Workers Compensation claims, following mTBI. Overall the results of the present study support the hypothesis that postconcussive patients who are involved in medico-legal proceedings differ in terms of subjective impairment and adaptability than those who are not involved in such proceedings. More specifically, it was determined that postconcussive patients involved in medico-legal proceedings endorsed greater subjective impairment and lower levels of adaptability following mTBI than those who are not.

This finding is consistent with an ample body of research that has suggested that increased reporting of symptoms following mTBI may be associated with litigation or compensation-seeking (Binder & Rohling, 1996; Paniak et al., 2002; Ruff, Wylie, & Tennant, 1993). In a study that examined claimants seeking compensation, Green and colleagues (2001) found that individuals with mTBI demonstrated poorer effort, more symptoms, and worse cognitive performance than those who sustained more severe brain injuries. Similarly, postconcussive patients seeking financial compensation have been found to consistently report greater symptoms-related impairment and distress over time as compared to non-seekers (Paniak et al., 2002).

The impact of financial incentive on outcome after mTBI was highlighted by a meta-analytic review conducted by Binder and Rohling (1996), who reported a moderate overall effect

size ( $d = .47$ ) between the two variables and found that financial incentive accounted for 23% of post-mTBI complaints. After summarizing the effects of financial incentive and litigation stress on the development/maintenance of persistent postconcussive sequelae, Iverson and colleagues (2006) concluded that exaggeration of symptoms is common among those undergoing evaluation related to medico-legal proceedings. Providing further evidence of the association between financial incentive and poor outcome after concussion is the work of Tsanadis and colleagues (2008), who identified compensation-seeking as a potential risk factor for the development of persistent postconcussive symptoms.

The role financial incentives play in the development and maintenance of symptom-related disability following mTBI has been a hotly contested issue for the past century (McCrea, 2008). Some have argued that overly focusing on the monetary aspects and secondary gains associated with medico-legal proceedings oversimplifies and under-analyzes the problem by failing to consider other influential factors inherent to the financial compensation process (Silver, 2011; Tyndel & Egit, 1988). Supporting this assertion is the finding that postconcussive symptoms persist in affected individuals after settlement of litigation proceedings and claim settlement (Binder & Rohling, 1996). It has been argued that what appears to some as suboptimal effort and symptom magnification may actually result from a combination of complex, and unconscious, psychological processes (Silver, 2012).

It has been well documented that stress, anxiety, and expectations regarding prognosis exert considerable influence over symptoms following mTBI (Deb et al., 1999; Feinstein et al., 2001; Ponsford et al., 2012; Silver, 2012). Reactions of stress and anxiety that interfere with cognitive performance in testing situations can also result from stereotype threat, or fear that one will confirm a negative belief about a subgroup they belong to (Chasteen et al., 2005). It is a

common perception that brain injury results in cognitive impairment. If one assumes this bias, and as a result maintains a strong belief that sustaining an mTBI will significantly impair their cognitive functioning, fears that this will occur may actually serve to undermine their performance in testing situations (Silver, 2012).

Participation in medico-legal proceedings that involve financial incentive may heighten one's perceived health vulnerability, resulting in increased focus on, and sensitivity to, somatic symptoms. Further contributing to the problem is the impact of under-recognized psychiatric disorders and health conditions that also contribute to the complex presentation of symptoms reported (Silver, McAllister, & Yudofsky, 2011). The present study found that subjects with a history of chronic pain were slightly more likely to be involved in medico-legal proceedings that involved financial incentive ( $n = 16$ , 44.4%) following mTBI than those without premorbid chronic pain ( $n = 9$ , 39.1%). A history of clinically significant psychological distress was also more common among these subjects ( $n = 19$ , 76%). This is consistent with findings from a study by Mooney, Speed, and Sheppard (2005) that focused on sub-optimal recovery following mTBI in individuals involved in medico-legal proceedings, which found that psychological disturbance and pain were among the variables most strongly related to outcome.

Unlike other neurological disorders that are definitively diagnosed with objective medical procedures, individuals with persistent postconcussive sequelae following mTBI are often doubted regarding the veracity of their symptoms and face adversarial situations to determine the effects of non-injury motivational factors, i.e. potential secondary gains (Silver, 2012). Additional stress and anxiety related to such proceedings may serve to exacerbate the perception of changes following mTBI, leading to increased self-report of postconcussive sequelae (Mittenberg, Tremont, Zielinski, Fichera, & Rayls, 1996). This assertion is supported by the



finding that co-occurring anxiety and post-traumatic stress can serve to exacerbate impairment and complicate prognosis following mTBI (Deb et al., 1999; Dikman, McLean, & Temkin, 1986, Silver, 2012). Feinstein and colleagues (2001) found that individuals involved in medico-legal proceedings related to mTBI demonstrated greater anxiety, psychosocial dysfunction, and poorer outcome than those who were not pursuing claims that involved financial incentive. This is consistent with the finding that shorter injury-to-settlement intervals are associated with less psychiatric disturbance (Binder, Trimble, & McNiel, 1991).

The adversarial environment associated with compensation and litigation proceedings may result in feelings of anger, revenge, and loss aversion, particularly if the claimant feels their injury-related suffering has not been acknowledged (Silver, 2012). Negative experiences that serve to question the injured party's integrity and further undermine their suffering, such as independent medical evaluations, can amplify feelings of anger, resentment, and loss that may translate into more intense and/or chronic postconcussive symptoms. This assertion is supported by research by Tennen and Affleck (1990), who found that blaming others for threatening events was associated with poor physical and emotional functioning. These findings are also consistent with studies that suggest that medico-legal proceedings involved in compensation litigation and insurance claims prolong post-injury recovery following mTBI (Martelli, Zasler, Hart, Nicholson, & Heilbronner, 2001; Rohling, 2000; Rohling & Binder, 1995).

Although the need to consider possible secondary gain as an individual force in PCS has clearly been demonstrated in the past and supported by findings from the present study, the use of objective clinical judgment cannot be underestimated in the assessment process. As accurate as current neuropsychological validity measures and instruments may be, they are far from infallible and one must always take care to consider the potentially large number of false

negatives that often accompany standards associated with low false positive rates (Martelli, Zasler, Bender, & Nicholson, 2003; Roskes, 1997). The need for thorough differential diagnosis in the assessment of postconcussive patients involved in medico-legal proceedings is further highlighted by the work of Greiffenstein and Baker (2001), who call for consideration of a wider range of pre-injury adjustment issues.

### **Limitations & Future Implications**

The present study has several limitations that should be considered when interpreting the associated results. Archival data was collected from a rehabilitation center that provides services for a considerable fee and, thus, our results were largely based on a select subset of individuals in the chronic stage of recovery after mTBI that had access to non-acute healthcare services, e.g. through private insurance or Workers Compensation. These restrictions are in keeping with the demographics of our sample, with almost half of subjects having sustained work-related injuries. As such, findings from the present study may not be representative of the general population, that is, all individuals who develop postconcussive sequelae following mTBI. This limits the generalizability of these results to postconcussive patients who have access to non-acute rehabilitative services. Further research is required to determine whether these findings are applicable to a more diverse patient population.

The presence of premorbid chronic pain, psychological distress, and other persistent health conditions was based on information contained in subjects' medical records. More specifically, this information was obtained from their initial medical evaluation report, which provides documentation of pre-injury health conditions and chronic pain. Due to the archival nature of the data, and the fact that pain represents an internal experience that defies objective measurement, there was no way to confirm the accuracy of participants' medical history or pre-

injury health conditions. It is estimated that the vast majority of individuals in the community who meet criteria for chronic pain or suffer from clinically significant psychological distress do not actually seek treatment from a health professional. As such, the number of subjects with a documented history of chronic pain or emotional distress whose information was reviewed for the purposes of this study was likely an underestimate, and caution should be taken regarding the generalizability of results to the general public.

Though statistical analyses revealed a statistically significant association between premorbid chronic health conditions and adaptability among postconcussive patients, the majority of subjects comprising this group had at least one medical diagnosis commonly associated with persistent pain. The considerable overlap between those who likely had premorbid chronic pain in addition to a chronic health condition represents a significant confound, as the relative influence of the two factors is unclear. In order to clarify the difference between those with and without a chronic health condition, future investigations would have to target individuals with medical diagnoses that have a high degree of illness intrusiveness that do not typically involve persistent pain.

Another limitation of this study was the authors' decision not to utilize a statistical method to counteract the problem of multiple comparisons across the data set. The decision not to adjust the level of statistical significance ( $p$  value) for the number of analyses performed was based on the rationale that doing so would increase the likelihood of Type I errors, or false-negatives, such that important differences between groups would be deemed to be non-significant (Perneger, 1998). For this reason, further research using a larger sample of postconcussive patients is needed to confirm these results. Nonetheless, because the level of statistical significance was not adjusted, the likelihood of obtaining false-positives, that is Type I

errors, was increased. If this were to occur, it is possible that results may be incorrectly reported as statistically significant.

Despite these limitations, the present study served to further expand our understanding of contributory mechanisms involved in the development and maintenance of postconcussive sequelae following mTBI. The significance of findings that emerged in the present study highlight the need for additional studies to examine the role of premorbid health factors and coping liabilities on the development and maintenance of postconcussive sequelae following mTBI. If the results of this study are replicated by future research, they may have important implications for the assessment and treatment of this patient population.

Results from this study also highlight the importance of tailoring assessment and therapeutic approaches to the unique presentation of the individual. Thorough consideration of biopsychosocial factors and pre-existing conditions may be particularly relevant in cases wherein prolonged postconcussive sequelae seem out of proportion to what is known about the nature and severity of the injury, as failure to do so may result in erroneous conclusions or ineffective treatment plans.

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